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Vol. XLV. No. 1.

REPORTS ON THE SCIENTIFIC RESULTS OF THE EXPEDITION TO THE TROPICAL PACIFIC, IN CHARGE OF ALEXANDER AGASSIZ, BY THE U. S. FISH COMMISSION STEAMER "ALBATROSS," FROM AUGUST, 1899, to JUNE, 1900, COMMANDER JEFFERSON F. MOSER, U. S. N., COMMANDING.

XIV.

THE SOLENOGASTRES.

By HAROLD HEATH.

WITH FORTY PLATES.

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CAMBRIDGE, U. S. A.:
Printed for the Museum.
June, 1911.

TROPICAL PACIFIC.

The following Publications of the Museum contain Reports on the Dredging Operations in charge of Alexander Agassiz, of the U. S. Fish Commission Steamer "Albatross," during 1899 and 1900, Commander Jefferson F. Moser, U. S. N., Commanding.

I. A. Agassiz. Preliminary Report and List of Stations. With Remarks on the Deep-Sea Deposits by Sir John Murray. Mem. M. C. Z., Vol. XXVI. No. 1. January, 1902. 114 pp. 21 Charts.

II. A. G. Mayer. Some Species of Partula from Tahiti. A Study in Variation. Mem. M. C. Z., Vol. XXVI. No. 2. January, 1902. 21 pp. 1 Plate.

III. A. Agassiz and A. G. Mayer. Medusæ. Mem. M. C. Z., Vol. XXVI. No. 3. January, 1902. 40 pp. 13 Plates, 1 Chart.

IV. A. Agassiz. The Coral Reefs of the Tropical Pacific. Mem. M. C. Z., Vol. XXVIII. February, 1903. 33, 410 pp. 238 Plates.

V. C. R. Eastman. Sharks' Teeth and Cetacean Bones from the Red Clay of the Tropical Pacific. Mem. M. C. Z., Vol. XXVI. No. 4. June, 1903. 14 pp. 3 Plates.

VI. W. E. Hoyle. Cephalopoda. Bull. M. C. Z., Vol. XLIII. No. 1. March, 1904. 71 pp. 12 Plates.

VII. H. Ludwig. Asteroidea. Mem. M. C. Z., Vol. XXXII, July, 1905. 12, 292 pp. 35 Plates, 1 Chart.

VIII. W. E. Ritter and Edith S. Byxbee. The Pelagic Tunicata. Mem. M. C. Z., Vol. XXVI. No. 5. August, 1905. 20 pp. 2 Plates.

IX. Mary J. Rathbun. The Brachyura. Mem. M. C. Z., Vol. XXXV. No. 2. August, 1907. 54 pp. 9 Plates.

X. C. H. Gilbert. The Lantern Fishes. Mem. M. C. Z., Vol. XXVI. No. 6. July, 1908. 23 pp. 6 Plates.

XI. A. Agassiz. Echini. The Genus Colobocentrotus. Mem. M. C. Z., Vol. XXXIX, No. 1. November, 1908. 44 pp. 49 Plates.

XII. J. Murray and G. V. Lee. The depth and marine deposits of the Pacific. Mem. M. C. Z., Vol. XXXVIII, No. 1. June, 1909. 170 pp. 5 Plates. 3 Maps.

XIII. W. C. Kendall and E. L. Goldsborough. The Shore Fishes. Mem. M. C. Z., Vol. XXVI. No. 7. February, 1911. 106 pp. 7 Plates.

XIV. H. Heath. The Solenogastres. Mem. M. C. Z., Vol. XLV. No. 1. June 1911, 180 pp. 40 Plates.

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THE SOLENOGASTRES.

INTRODUCTION.

The present paper embraces the results of the study of a collection of over three hundred specimens of Solenogastres, which have been taken in the Pacific during the various expeditions of the U. S. Fish Commission Steamer "Albatross." Based primarily on material from the Museum of Comparative Zoölogy, it includes, through the generosity of the late Mr. Alexander Agassiz, the description of other species collected during recent years. The territory embraced in these explorations is very extensive, including the entire coast of North America from Lower California to Bering Sea, the Kurile Islands, the Japanese Archipelago, and the Hawaiian Islands. The major portion of the material was collected by the following expeditions: Tropical Pacific, 1899-1900; Hawaiian Exploration, 1902; Alaska Investigations, 1890 and 1903; California Coast Exploration, 1889 and 1904; Japanese Expedition, 1906.

Species	Station	Number of Specimens	Depth in Fathoms	Locality
Chaetoderma argentea	4231	1	82–113	Alaska, near Naha Bay.
" attenuata	4244	1		
	4250	5	50–201	" vicinity of Pr. Wales Id.
	4252	2		
" californica	4381	1	618–667	California; S. pt. N. Coronado Id.
" erudita	4258	10		Alaska, Lynn Canal.
	4264	41	282–313	" Chatham Strait.
" hawaiiensis	3992	1	283–528	Hawaiian Ids.; near Kauai Id.
	4130	1		
" japonica	3721	1	207–250	Japan, S. of Honshu Id.
" montereyensis	4485	9	39–356	California, Monterey Bay.
	4508	7		
	4522–4525	139		
" nanula	4369	1	260–284	" off San Diego.
" robusta	3210	4	483	S. of Alaska Peninsula
" scabra	4538	1	795–871	California, Monterey Bay.

Species	Station	Number of Specimens	Depth in Fathoms	Locality
Limifossor talpoideus	4258	4	282–313	Alaska, Lynn Canal.
	4264	6		" Chatham Strait.
" fratula	4369	2	260–281	California, off San Diego.
Drepanomenia vampyrella	3907	1	304–315	Hawaiian Ids., off Oahu Id.
Pachymenia abyssorum	4397	1	2196–2228	Off southern California.
Proneomenia hawaiiensis	3864	2	163–277	Hawaiian Ids.
	4004	1		
" insularis	4157	1	762–1000	" " near Bird Id.
Driomenia pacifica	3716	3	65–125	Japan, Ose Zaki; vicinity of Misaki.
	4935	1		
Dorymenia acuta	4407	2	302–638	Off southern California.
	4415	6		
	4416	3		
Strophomenia farcimen	3748	2	73–200	Japan, S. of Honshu Id.
" ophidiana	3755	1	52–77	" " " " "
" regularis	3717	1	63–100	" " " " "
" scandens	4156	3	286–568	Hawaiian Ids., near Bird Id.
" spinosa	3718	1	73–200	Japan, S. of Honshu Id.
	4935	2		
	4936	2		
" triangularis	3716	2	65–125	" " " " "
	4935	2		
	4936	1		
Lophomenia spiralis	4176	2	537–672	Hawaiian Ids., near Niihau Id.
Alexandromenia agassizi	2992	6	460	Revillagigedo Ids. off Mexico.
" valida	2980	1	603–1350	Off S. California.
	4382	1		
	4389	1		
	4391	1		
Halomenia gravida	4804	2	220	Kurile Ids., near Simushir Id.
Herpomenia platypoda	4781	11	482	Aleutian Ids., near Agattu Id.
Dondersia californica	4303	1	21	California, off San Diego.
Ichthyomenia porosa	4400	20	500–542	" " " "
	4402	2		

Up to the present time none of these molluscs has been described from the North Pacific. A few species are known to occur about Australia and the Philippines, and an extensive collection was made in the East Indian Archipelago by the Siboga Expedition. The present collection embraces thirty-one species of which all are new with the exception of *Limifossor talpoideus* Heath; the species belong to fourteen genera of which eight are new. From this material it becomes increasingly evident that this group of molluscs is cosmopolitan; but there is no evidence of a bipolarity or any indication that the north and south poles were centres of distribution. And furthermore there is no apparent relation between size and geographical distribution.

In concluding this section of the paper it becomes a most pleasant duty to express my obligation to those who have aided in its completion. To Hon.

G. M. Bowers, Dr. D. S. Jordan, and Dr. C. H. Gilbert I am indebted for a portion of the material, to certain data relating to a few of the species and for many courtesies while on board the "Albatross." I am likewise under deep obligation to Drs. E. J. Nolan and H. A. Pilsbry for the use of the magnificent library of the Philadelphia Academy of Sciences, and for several suggestions of a most helpful character. To Dr. W. K. Fisher I am indebted for the identification of the alcyonarian hosts and for a specimen of *Chaetoderma hawaiiensis*. I also wish to express my gratitude to my assistants, Miss R. M. Higley, and Mr. F. W. Weymouth who have greatly lessened the burden necessarily involved in such a study as this. And finally my indebtedness to the late Mr. Alexander Agassiz is very great; in every way possible he helped the work along.

HISTORICAL REVIEW.

The first known reference to any species of Solenogastre occurs in the works of Loven, who in 1844 briefly described as a gephyrean worm *Chaetoderma nitidulum*. During the next thirty years a number of systematists adopted this scheme of classification though there was some difference of opinion concerning the exact position of the species within the group. Diesing ('59), Keferstein ('65), Quatrefages ('65), and Baird ('68) allied it to Sipunculus or Priapulus; Theel ('75) created for it a new family (Chaetodermidae), while M. Sars ('69) placed it among the gephyreans without any comment. Dalyell ('53) in "The Powers of the Creator" gives under the name *Vermiculus crassus* an abbreviated description and one figure of an undoubted Chaetoderma, according to Koren and Danielssen ('77) *C. dalyelli*, but the description is much too indefinite to make the determination certain.

During this time M. Sars discovered another species of Solenogastre, belonging to a new genus and ultimately to a new family, which he placed ('69) among the Mollusca without any comment whatever, merely giving it the name *Solenopus nitidulus*. Some years later Tullberg ('75) described what is considered to be the same species under the name *Neomenia carinata*. This last named author's investigations mark a distinct advance in our knowledge of these forms, since they are concerned not only with the study of the external characters but with the internal organization as well. In certain respects, especially in the treatment of the urogenital system, the work is seriously at fault, but nevertheless it was thoroughgoing enough to lead Tullberg to conclude that, while the species is vermian in what he considered to be probably the most important characters, it is on the other hand decidedly similar to certain of the Mollusca.

In 1876 von Graff subjected *Chaetoderma nitidulum* to an examination, which considering the amount of material and the methods then in vogue, was more than ordinarily searching; and while he, like Tullberg, fell into error regarding the urogenital organs, his results relating to the other systems, especially the nervous, were of the greatest importance. While not entirely committed to any particular belief regarding the animal's relationships he was inclined to uphold Keferstein, Diesing, and others; and yet he drew attention to the fact that the spicules, gills, mode of egg development, and musculature are so unique that the genus may in reality belong elsewhere, possibly in close proximity to the Turbellaria owing to the close correspondence in the nervous systems.

In 1877 and the following year von Ihering proposed a new classification of the Mollusca based on extensive anatomical researches largely concerned with the nervous system. He drew attention to the very important fact, not previously recognized, that in many fundamental respects the Solenogastres are allied to the Chitons. In his opinion the ancestral neomenian was probably not distantly related to the gephyreans or nemerteans and accordingly lacked a true shell, and Chitonellus, with its small shell and extensive girdle, is thus more closely related to the Solenogastres than other Chitons and must therefore be looked upon as a connecting link. Owing to the presence of lateral nerves the Chitons, Chitonellus, and the Solenogastres are clearly differentiated from the gephyrean worms and annelids, so that in this and other respects they approach the molluses. On this account a new phylum of Vermes, the Amphineura, was created for their reception. The following year ('78) this same author reviewed the work of Tullberg, Koren and Danielssen, and von Graff in a suggestive paper, and was more strongly convinced than before that his conclusions were justified. These papers of von Ihering's created much criticism, some of it decidedly hostile, but it is undoubtedly true that, while some of the results have not proved to be correct, the work as a whole had a stimulating effect and has been productive of much good.

During this same period ('77) Koren and Danielssen described a number of species collected along the Scandinavian peninsula. In most cases the descriptions are so brief that they are not even of generic value, and the animals remain practically unknown down to the present day. *Neomenia carinata* (*Solenopus nitidulus*) is described at some length, but the facts adduced are not strikingly different from those presented by Tullberg. By these authors the Solenogastres were considered to be true molluses, and were placed among the opisthobranchs in a new order, Telobranchiata.

During this same year Lankester ('77) placed himself on record to the effect that members of the genus Neomenia are among the most generalized molluscs, related to the Chitons and Chitonellus, yet belonging apart in a phylum which he termed Scolecomorpha, the first division of Mollusca encephala.

Another of the important papers which appeared during this year came from the hand of von Graff, who investigated the anatomy of *Neomenia carinata* and reexamined *Chaetoderma nitidulum*. From the facts disclosed this author was convinced that not only are the two forms constructed upon the same plan, but that the establishment of the Amphineura as a separate phylum by von Ihering was wholly justified. "Wir erkennen in Neomenia und Chaetoderma Modificationen einer sehr alten Urform, vom denen die letztere näher den Würmer, die erstere näher den Mollusken anknüpft." In quite a remarkable way the facts discovered in the study of these two species supported von Ihering's contention that the Solenogastres and the Chitons are allied forms, though they did not force one to the belief that the Amphineura are necessarily to be placed in the phylum Vermes, and von Ihering himself abandoned this position a short time later.

About the same time Hansen ('77) published a most important paper on the anatomy of *Chaetoderma nitidulum*, and in the treatment of all the systems, especially the urogenital, advanced our knowledge to a considerable extent beyond the old position. For the first time the mode of development of the sex products was determined, and their route traced to the exterior; in other words the broader features of the anatomy of Solenogastres now became comprehensible. In the opinion of the author, Chaetoderma does not clearly belong to any definite place in the existing system of classification; that while certain molluscan characters appear, others are strongly suggestive of annelid relationships, so that its exact position is yet in doubt.

The following year Gegenbaur ('78) in the "Grundrisse" made a few very guarded statements regarding the relationships of Neomenia and Chaetoderma which may, provisionally at least, be designated the Solenogastres and may be regarded as a division of the group Vermes. The ventral groove of Neomenia "represents the first stage in the formation of that pedal surface of the body which is seen in the lowest Mollusca." On the other hand the nervous system, while decidedly different from that in the worms, nevertheless presents some fundamental resemblances.

With the exception of two or three short notices no other papers appeared until 1881, which in some respects is the most important year in the history of

the group. At this time Spengel described the innervation of the osphradium, and in several species of molluscs discovered deep-seated resemblances in the elements of the nervous system and their arrangement. On the basis of this work, which includes the examination of Neomenia, Chaetoderma, and two unidentified species of Solenogastres, and with the additional help afforded by the work of Tullberg, von Graff, and Hansen he emphatically claimed, in opposition to von Ihering and Gegenbaur, that the Amphineura are true molluscs. Accordingly he established the Amphineura (Chitons and Solenogastres) as a class of the Mollusca.

A very short time afterward the masterly work of Hubrecht appeared, and in some respects it continues to be the most important work that has ever been published on the subject. The study was based chiefly upon a gigantic species, *Proneomenia sluiteri*, which occurs in Barents Sea north of Scandinavia, and embraced a careful examination of its external and internal anatomy. The results, with a few relatively unimportant exceptions, have been confirmed by the study of many other species, and form a most substantial foundation for studies of more recent date. Concerning the relationships of Proneomenia, Neomenia, and Chaetoderma the author has no hesitancy in agreeing with Spengel that they constitute one order (Solenogastres) of the class Amphineura, the Chitons belonging to the other (Polyplacophora). In a number of succeeding publications this position is held without modification, and the few additional facts of importance that are presented still further emphasize the correctness of the theory.

From this time forth scarcely a year has elapsed without one or more papers appearing on the subject of the Solenogastres. Deep-sea researches or work along the shore line beyond the littoral zone have brought to light an ever increasing number of species whose anatomy is now for the most part fairly well known. Without exception all are built upon essentially the same fundamental plan though in detail each species presents, as is to be expected, some new and interesting modifications. To the majority of zoölogists the accumulated results point unmistakably to the true molluscan nature of these animals, but a glance through some of the succeeding paragraphs will show that there is far from being a unanimity of opinion regarding their position in the phylum and their relation to other groups. The great mass of anatomical details which have been published during the past twenty-five years, serving chiefly to distinguish genera and species, new and interesting though they may be, can be but briefly considered in a review of this character.

In 1882 Kowalevsky and Marion called in question the work of all preceding authors, claiming that they in every case had wrongly oriented the animals, that the anterior end is in reality posterior and *vice versa*. Tullberg's lateral glands (portion of the coelomoducts) are accordingly the salivary glands, the penis with its appendages is clearly the radula, the mouth cavity is the rectum, the "egg bag" (pericardium) is the intestinal coecum above the pharynx, the branchia are the buccal cirri and finally the protrusible pharynx is the combined uterus and oviducts.

This paper called forth an immediate rejoinder on the part of Hubrecht, who reviewed the work of the authors in question, and showed that the orientation of the animals in question is correct, and that Kowalevsky and Marion have created confusion worse confounded owing, for one reason at least, to the fact that they had not seen the species under discussion.

During the next four or five years Kowalevsky and Marion published, either separately or conjointly, several papers preliminary to their chief work which appeared in 1887. In this study the authors describe to a certain extent the habits of five new species of these molluscs collected along the shores of France, and accompany it with a very detailed description of the external and internal anatomy. Some of these last named results are referred to elsewhere in the present paper.

In the meantime Selenka ('85) published an account of the gephyrean worms collected by H. M. S. Challenger, and therein briefly described *Chaetoderma militare* from the Malay Archipelago, adding the remark that he was unable to give any data that might settle its systematic position.

In 1888 Hubrecht described a new genus of Solenogastres (Dondersia) taken in the vicinity of Naples. It is a fairly close relative of Proneomenia and Neomenia, and the anatomical characters are accordingly not strikingly different from those presented in the paper on *P. sluiteri*.

In this same year Hansen ('88) made a study of several species of Solenogastres long before described by Koren and Danielssen ('77). His researches chiefly concern *Neomenia carinata*, which is shown more conclusively than before to be similar to *P. sluiteri*. *Chaetoderma nitidulum* was found to pass the sex products into the pericardium from whence they pass through ducts into the anal cavity (Hubrecht) or branchial cavity (Hansen).

Pruvot ('90) denied the existence of a heart, or pericardium or dorsal aorta in the Solenogastres. The blood moves in lacunae of which a large one passes dorsally along the mid line propelled by contractions of the body. The paired

gonad, posteriorly becomes single, and opens into what has been termed the pericardium, in reality an accessory part of the reproductive system; while the dorsal sinus courses in a tube (hanging partially in the so-called pericardium), which is called, by other authors, the heart. In *Dondersia banyulensis* spermatozoa develop on the external walls of what has been termed the heart, while the lateral walls of the pericardium are ciliated and serve to convey the sperms as in many hermaphroditic gastropods. Eggs are temporarily stored in the "poche accessoire" (pericardium), and the kidneys are in reality genital ducts without renal function.

In a later paper ('90) the same author describes a few very interesting stages in the development of *Dondersia banyulensis*, and two years afterward adds some further observations regarding the embryology of *Proneomenia aglaopheniae*. Ova in the pericardium (of other authors) lack membranes; as these are present in extruded eggs it follows that the supposed kidneys are in reality shell glands. The segmentation stages resemble those of scaphopods and pelecypods, and to some extent this similarity is visible in the later development. A gigantic coat of ciliated cells (a highly developed velum probably) is formed, and within this the embryo forms by a process certainly not primitive or at all events unlike that of other molluses studied up to the present time. When the velum is thrown off the larva resembles to some extent a young Chiton, possessing seven imbricated calcareous plates along the dorsal surface and laterally situated flattened spines in what appears to be the girdle. The internal organs at this stage are practically undeveloped, and as the later growth is wholly unknown the present results throw but little light upon the important subject of the phylogenetic development of the group.

Pelseneer ('90) considered (*contra* Hubrecht and others) that Chitonellus is not a primitive form intermediate between the Solenogastres and more typical Chitons, but on the other hand is highly specialized. These conclusions were based on data supplied by a study of the branchia, nervous system, and shell. In an introduction to the extensive work of Blumrich ('91) Hatschek seconds Von Ihering in his attempt to place the Chitons and the Solenogastres apart from the gastropods, and agrees also with Pelseneer in regard to the position of Chitonellus.

Owing to the studies noted in the preceding paragraphs the broader features of the anatomy of these animals have been settled beyond dispute, and consequently the papers from this time forward serve in large measure to supply details, and to a limited extent indicate the phylogenetic relationships of this

group of animals. The more special features relating intimately to the various systems are noted to some extent in the main body of the present paper, while the general considerations are discussed on p. 164-173. Among the more extensive of these works are those of Pruvot ('91), who has described several species from the shores of France; Wiren ('92) whose study of several species from the Scandinavian coast is among the best that has ever appeared; Simroth ('93) and Pilsbry ('98) whose systematic works are of the highest value; Thiele whose various papers during the past fifteen years have added materially to our knowledge of the anatomy of molluscs, including several species of Solenogastres; Nierstrasz (1902, etc.), who with an abundance of material collected chiefly by the Siboga Expedition, has added extensively to our information of these animals; and finally the present writer who has contributed some data relating especially to the nervous system.

Since the above was written Nierstrasz has published an important report (1908) reviewing the work of various investigators since the appearance of Simroth's paper in 1893. It is a valuable contribution, and the scheme of classification there adopted will be of much service.

Turning now to the broader features of the classification of these animals we find that practically every investigator in this field of research is agreed with Spengel that among the Mollusca their nearest relatives are the Chitons; but regarding their more accurate position within the phylum differences of opinion appear. Von Ihering in 1877 called attention to the fact that the Solenogastres and the Chitons are not distantly related, especially if we consider Chitonellus to be a connecting link and therefore a primitive animal. According to this line of reasoning the Solenogastres, devoid of a radula (none had been discovered at that time) and shell, are the more ancestral and are so closely related to the worms that both they and the Chitons constitute a special phylum (Amphineura) of Vermes as noted in a previous paragraph. Hubrecht, without laying much stress on the ancestry of the Amphineura, though he hints at their derivation from a platyhelminth ancestor, was likewise of the opinion that the Solenogastres are primitive, and that Chitonellus is a link connecting them with the more highly modified Chitons. It may be mentioned also that Haller in '94 modified some of his previous ideas, having become convinced of the correctness of von Ihering's and Hubrecht's position.

The above idea was combated by Pelseneer ('90) who claimed that Chitonellus is nothing more than a highly modified Chiton and in no direct way related to the modified group of the Solenogastres. Hatschek ('91) agreed with this

theory though he did claim with von Ihering (a theory abandoned by him in '90) that the Amphineura are Vermes. Grobben ('94) likewise considered this the correct view though he believed the Amphineura to be true molluscs. This notion is implied in the work of Haller ('82), who made the claim that the Chitons and the Solenogastres are distinct groups of animals which have been derived from a common vermian ancestor. In a more vigorous fashion Thiele argues from the same standpoint.

With one or two exceptions those who argue along the line just indicated regard the Solenogastres as primitive animals, and are accordingly opposed to several investigators who hold a diametrically opposite view. Simroth, Wiren, and Heath believe that the Solenogastres early branched off from some primitive polyplacophore and while retaining several primitive features are in other respects degraded organisms. Pelseneer and Garstang take practically the same view. Marion, in a sense, does the same as he compares the adult Solenogastre to the larva of the Chiton. Plate traces the Solenogastres and Chiton lines of descent to some ancestral mollusc which may have given rise also to the present classes.

In regard to the derivation of the molluscs, and the Solenogastres especially, from some premollusean ancestor there are a number of widely divergent theories. In 1877 von Ihering believed that among the worms the gephyreans are most closely related to the Solenogastres. Haller ('82) on the other hand regarded them as more closely allied with the nemerteans. Hubrecht, Thiele, Plate, and a number of other writers consider that the molluscs, or at all events the Solenogastres, arose from a turbellarian-like ancestor. This idea has been most fully developed by Thiele. According to him the progenitor of the molluscs and the Solenogastres (which are considered to be worms) was in the fundamental characters of its organization similar to the modern cotylean polyclad. The often frilled sensory margin of the body became the mantle, which for purposes of protection, developed a cuticular covering and ultimately a shell, while the ventral sucking disc expanded into the mollusean foot which in its least modified form occurs in Haliotis and similar species.

GENERAL FEATURES, METHODS, ETC.

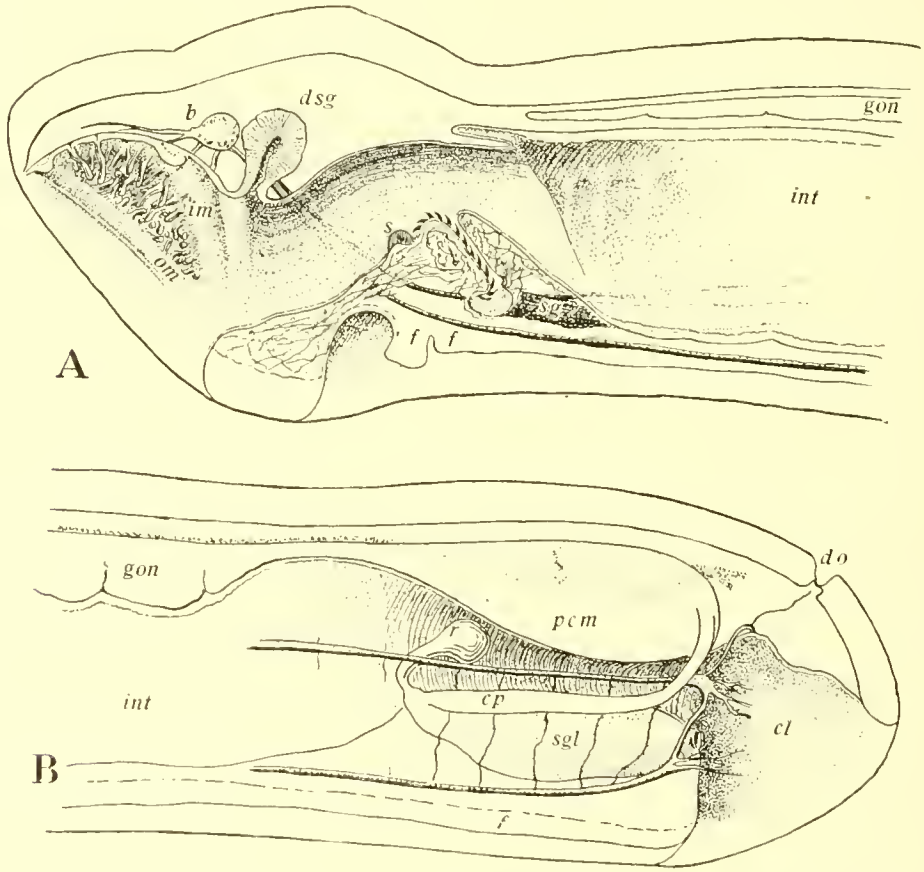
External Characters.— The Solenogastres constitute a group of marine animals, which combine with features more primitive than in any other molluscs numerous others indicating a high degree of modification. All are bilaterally symmetrical, worm-like in form, usually nearly round in cross section, and vary in shape from short thick set to very slender greatly elongated types. While the average length is not far from twenty-five millimeters several species such as *Notomenia clavigera* and *Kruppomenia minima* are from one to four or five millimeters long, and on the other hand *Proneomenia sluiteri* reaches the giant size of one hundred and forty-eight millimeters.

The mouth, or more properly the atrial opening, usually in the form of an elongated slit, holds an antero-ventral position, and is clearly separated from a ventral median furrow, in the Neomeniina extending throughout the entire length of the body. This latter structure is generally considered to be a true pedal groove, the small fold included therein and abundantly provided with glands being the foot. In the Chaetodermatina no external trace of these organs exists, but a gap in the ventral musculature, and a thickening of the muscle bands on each side of the mid line, and in Limifossor a definite pedal sinus, indicate that they were present at a former time. In what must be considered a primitive condition the ventral furrow is posteriorly continuous with what has usually been termed the cloacal cavity, which contains the openings of the urinogenital apparatus, anus, and the respiratory organs. As is more fully shown in a succeeding paragraph, the cloaca is in reality a mantle cavity, and the two branchiae it contains in the Chaetodermatidae are undoubtedly true ctenidia. On the other hand the folds of the cloacal wall, sometimes excessively developed and highly vascular, do not appear to be rudimentary nor degenerate ctenidia.

A cuticular sheath, often of great thickness, envelops the body, and contains from one to seven or eight layers of calcareous spicules. Where more than one layer is present groups of cells constitute papillae or organs of problematical use. In the adult condition all traces of a shell are absent, but in the development of *Myzomenia* (*Dondersia*) *banyulensis*, as determined by Pruvot, a stage occurs in which the embryo bears on its dorsal surface seven slightly imbricating, calcareous plates.

Internal Anatomy. — In regard to the internal organization there are numerous features that indicate a degraded condition, due probably to parasitic

habits or an adaptation for a life in the bottom ooze. In Chaetoderma the alimentary tract is a comparatively simple tube passing directly through the body, (as with other Solenogastres), provided with a radula, reduced to a single median tooth, and a voluminous unilobed liver. In other genera (Prochaetoderma, Limifossor) of the family the radula is of large size, and is typically formed and placed. In the Neomeniina this system is more complex. The first division of the digestive tract, which may be termed the atrium, probably corresponds to a highly modified buccal plate, and though usually connected with the mouth (Diagram p. 20, A) may be separated from it. The walls are modified into



Diagrams illustrating structure of a neomenian. A anterior end. b brain; dsg dorsal salivary gland; f foot; gon gonad; im, om inner and outer atrial ridges enclosing the cirrose area; int stomach-intestine; s subradular organ; sg ventral salivary gland. B posterior end. cl cloacal cavity; cp dorsal limb of gonoduct; do dorso-terminal sense organ; pcm pericardium; r seminal receptacle; sgl ventral limb of gonoduct or shell gland.

ridges and cirri, probably sensory structures. A radula is generally present though often greatly reduced in size. In addition to the dorsal salivary glands, probably existing in certain Chaetodermatina as well, a ventral pair is usually

attached near the radula. A definite digestive gland is wanting, the mid-gut pouches being lined with hepatic cells.

Owing to the great reduction of the foot and correlated changes, several peculiarities appear in connection with the circulatory system. As in the Chitons the heart is posterior, and the aorta passes along the mid line dorsal to the gonad to connect with the head cavity, which in Limifossor is limited posteriorly by a well-developed septum. In this genus there are indications also of a pedal sinus, but behind the head region it largely disappears, the blood flowing between the gut and body wall to the branchial region. Passing through the ctenidia, or the folds in the cloacal wall, when these are present, the blood makes its way to the posterior end of the heart.

The nervous system bears a striking resemblance to that of the Chitons. There is a greater concentration of the nerve cells to form well-differentiated ganglia, but otherwise there are, in such species as *Proneomenia hawaiiensis*, no especially unique features. The supraoesophageal mass originates three pairs of nerves, which innervate the buccal and neighboring body walls and three pairs of connectives, the labiobuccal, pedal, and lateral. The first named, in a typical condition, is decidedly Chiton-like both as regards its position and elements. The other two, passing backward throughout the entire length of the animal, are united frequently by commissures and connectives, and may fuse completely (Chaetodermatidae) in the cloacal region. In a number of other species the pedal cords, after diminishing in size in the hinder regions of the body, may lack any connection with the lateral ganglia, or they may terminate in ganglionic enlargements (*ganglion posterius inferius* of Wiren) united by connectives with similar swellings (*gang. post. superius*) on the end of the lateral cords. The latter ganglia are invariably united by a heavy commissure passing dorsal to the rectum, and the pedal cords likewise may be connected by a subrectal commissure, thus completing a circumrectal nerve ring.

In the Solenogastres the secondary body cavity comprises that of the gonad, pericardium, and the ducts leading from this latter space to the cloaca. In the Neomeniina the species are hermaphroditic; in the Chaetodermatina dioecious. The sexual elements pass through the pericardial cavity into the coelomoducts, which in an immature condition are relatively simple, and in some species at least are not fused before they open into the cloacal cavity, characters which the Chaetodermatina retain throughout life. In the Neomeniina, on the other hand, various modifications may occur which produce a high degree of complexity. Two or more seminal receptacles are usually present,

and the walls of the median undivided section and a portion of the canals leading on to the pericardium become greatly thickened to form the shell gland. Whether these canals ever function as kidneys is an unsettled question. In the Chaetodermatidae there are indications that they do, but at the present time there is no experimental evidence in support of such a view.

Our knowledge of the development of this group of animals is very incomplete. From Pruvot's work on *Myzomenia banyulensis*, and my own on Halomenia, it is evident that the early history resembles that of certain lamellibranchs and the scaphopods. Pruvot's interesting discovery of a stage where the embryo bears seven calcareous shell plates indicates, as a number of authors maintain, that the Aplacophora have descended from polyplacophorous ancestors.

Methods. — On several occasions I have tried the effects of various killing fluids, and am convinced that for general histological work alcohol is the most satisfactory and is easily controlled. Specimens from deep water are usually in a moribund condition when they come up in the dredge, and undergo practically no contraction when plunged directly into 70% alcohol. Where the animals are more hardy or have been taken in comparatively shallow water it is advisable to add gradually chloretone (aceto-chloroform) dissolved in alcohol until they are completely narcotized. They may then be placed in 70% alcohol for a few hours and preserved permanently in an 80% solution. In warm weather it is sometimes necessary to keep the specimens in a cool place until thoroughly fixed, and in any case it is necessary to use considerable quantities of alcohol. In the study of the nervous system I have found vom Rath's fluid highly satisfactory especially when the material is treated subsequently with a 1% solution of pyroligneous acid. When sufficiently oxidized the nerve fibres remain grayish in color and are usually quite distinct among the yellow muscle and connective-tissue fibres. For staining I have generally used Delafield's haematoxylin, rarely using rubin as a secondary stain.

In connection with certain features of the nervous system the specimens used were of sufficient size to allow of dissection. Under such circumstances paraffine was poured into a small dissecting pan and while it remained soft the mollusc was partially imbedded in it, thus obviating the use of pins. Dissection was done under alcohol by means of a needle mounted on the end of the arm of an instrument for mounting diatoms.

In removing the cuticle from about the spicules *eau de Javelle* is preferable to caustic potash which frequently exerts a decided corrosive action on the more delicate spines.

Occurrence. — Owing to the methods employed the Solenogastres described by the earlier authors, and a small fraction of those subsequently discovered, have been taken in comparatively shallow water, in a very few cases within the littoral zone. However it cannot be said that they are essentially shore forms, for the various deep-sea explorations of recent years have demonstrated that, in certain localities at least, they are a characteristic feature of the deeper regions of the sea and only exceptionally extend into habitats along shore.

With the publication of the present paper the number of species of Solenogastres reaches a total of ninety-two. In most instances these have been described from one or at most a very few specimens, but the scantiness of material appears to be the combined result of habitat and mode of capture. As mentioned in a succeeding paragraph, these animals are either attached to some coelenterate host or they burrow in the bottom ooze. In the first case they may be readily dislodged and lost; in the second they are usually out of reach. On several occasions, while acting as temporary naturalist on the U. S. F. C. Str. "Albatross," I have been able to examine carefully large quantities of mud, which has been scooped from the bottom, and have secured unusually large numbers of individuals of a few species. In Alaska (Sta. 4264), for example, the dredge load contained forty-seven specimens belonging to two different genera (*Limifossor talpoideus* and *Chaetoderma erudita*). Again in Monterey Bay, California, one haul (Sta. 4522) contained fifty-nine *Chaetoderma montereyensis*, while in a neighboring locality (Sta. 4523–4525) eighty were taken. In the National Museum I recently examined a large number of small animals taken by the "Albatross" in the Atlantic, and discovered no less than thirty specimens of these molluscs belonging to two genera. From such data and considering that the amount of territory explored is but a tithe of the entire sea floor, it is reasonable to suppose that in point of numbers and of species these animals will far surpass their nearest allies, the Chitons.

Owing to the fact that up to the present time no Solenogastres have been reported from the North Pacific, and since the species described in the present paper have usually been collected from widely separated stations in a single dredge haul, it follows that there is little to be said definitely regarding their general distribution. It is an interesting fact that of the eight species taken in Japan six belong to the genus Strophomenia. The genus Limifossor is represented by two species off Alaska and California respectively. This last named region is likewise the home of *Alexandromenia agassizi* and *A. valida*. Species of Chaetoderma occur in the ooze in all of the carefully explored terri-

tory mentioned in the introduction. However, it cannot be said that in any case we have any very definite information regarding the geographical limits or relative abundance of a single species.

There is little to be said regarding the vertical distribution of the species described in the present paper. Where several individuals have been secured from a number of stations each species appears to be restricted to a fairly definite depth. *Chaetoderma nitidulum* is reported to have a range of from 14–1250 meters. A much greater depth may be possible for *C. hawaiiensis* from Station 4130 where the initial sounding recorded 1362 fms.; but since the closing sounding was 358 fms. it is probable that the latter figure is more nearly correct, as a second specimen was taken at a depth of 528 fathoms (Sta. 3992). In many places the ocean floor is exceedingly rough and characterized by high almost vertical cliffs bounding fissure-like valleys. Under such circumstances a number of soundings are desirable in order to avoid the necessity of accepting great extremes in vertical distribution though these may in reality exist with certain species.

Mode of life, Food. — The species belonging to the Chaetodermatidae are, so far as known, inhabitants of the sea bottom where they excavate burrows which they rarely leave. Wiren ('92) who kept over one hundred specimens of *C. nitidulum* in captivity says they progress through the ooze by means of the alternate contraction and expansion of the prothorax aided by movements of the entire body; and that when at rest they ordinarily direct the body vertically with the cloacal chamber widely expanded, and the branchiae fully exposed at the opening of the burrow at the surface. When disturbed they disappear instantly several inches into the mud. In most respects these observations answer for *C. crudita* which I kept some time in captivity. This animal from time to time advanced through the ooze in the manner described by Wiren but it never appeared at the surface. For hours together it remained quietly in its burrow with the gills fully expanded and when disturbed retreated but slowly, though the gills were at once retracted and the cloacal chamber closed. The individuals acting in this manner were apparently in a normal condition since the alimentary canal of several kept in captivity for nearly one month contained quantities of food.

The members of the suborder Neomeniina, on the other hand, are not known to burrow, but are usually found on some species of hydroid, coral, and exceptionally (*Proneomenia vagans*, *P. desiderata*), on plants. Now and then specimens have been dredged unattached and it may be that they, like *Neomenia*

carinata and *Stylomenia salvatori*, crawl about freely over the sea bottom, though it is possible also that they have been loosened from some host.

The relation of mollusc and coelenterate has not been thoroughly worked out, but there are many indications and some definite proof that it is a genuine case of parasitism and not an accidental association or a case of commensalism. In *Drepanomenia rampyrella* from the Hawaiian Islands the proboscis of one individual was inserted into the body wall of some species of Epizoanthus, many of whose reproductive and other cells had been withdrawn so that here there is no doubt that this Solengastre is a parasite. The presence of nematocysts in the alimentary canal of several other species, including most of the species of Strophomenia, indicates that they likewise are in the same category. Hubrecht ('80) states that a bit of alcyonarian coral was found in the mouth of *P. sluiteri*, but he calls attention also to the fact that diatoms and entomostracans occurred in the faeces in the cloacal cavity, and Heuscher ('92) records the presence of Entomostraca in the gut itself. It thus develops that the diet of such species is varied, and it is possible that such forms as *P. vagans* and *P. desiderata* which were found crawling about on plants belong to this same class.

So far as known the food of the Chaetodermatidae consists of microscopic organisms and organic remains which they scoop up while burrowing through the ooze. Wiren ('92) believes that the buccal plate (Mundschild) acts as a digging organ, and this may indeed be the case but the exceedingly small amounts of inorganic material, which make their way into the digestive tract, indicate that in addition to functioning in a purely mechanical fashion it manifests a decided selective action. When selected the food is carried backward by the great conical tooth in the genus Chaetoderma, and in the form of a more or less spherical bolus, mixed with the secretion of the salivary glands, is carried into the mid gut. In Prochaetoderma and especially Limifossor the radula and its supports are of large size and indicate active, predatory habits, but the contents of the gut are essentially the same as in Chaetoderma.

Color, Size. — In a preserved state the skin of the Solenogastres is usually unpigmented, the light yellow or yellowish brown tint of the animal being due to the cuticle investing the body. In many species, especially of the Chaetodermatidae, this may be obscured to a greater or less degree by the multitudes of refringent spicules imbedded in it or by some of the internal organs. The liver for example is often dark brown, and shining through the translucent body wall and the overlying cuticle and spicules, gives a decided frosted gray tint to several species. The red color of the blood plasma may impart a pinkish tinge espe-

cially in the head and cloacal regions. An incrustation, rusty red or black, may cover the entire animal though it is usually restricted to the posterior extremity. In a very few species some of the hypodermal cells contain pigment, red, yellowish red, lilac, or yellow in color. *Echinomenia coralliophila*, a species living on *Corallium rubrum*, is provided with movable scales which when depressed give the body a whitish tint resembling the tentacles of the host, and this may possibly be the case with *Strophomenia spinosa*. Upon raising the spines the pigmented hypodermis becomes less obscured and the animal assumes a reddish color similar to the coral stalk.

The smallest sexually mature Solenogastres are not over 5 mm. long, and on the other hand *Proneomenia sluiteri* attains, as previously stated, the great length of 148 mm. The average length is probably not far from 30 mm.

Length Index. — In the discrimination of species the so-called length index, or the ratio of length to breadth of body, has been used to a considerable extent, but from several experiments in the preservation of fresh material, I am convinced that it is of little use, certainly not with closely related forms. For example nearly sixty *Chaetoderma nitidulum*, which had come up in the same dredge haul, were treated with slow alcohol in precisely the same fashion and yet the length indices varied fully twenty per cent. Some specimens must invariably be subjected to a greater pressure than others in the dredge haul, and these are more flaccid and less contractile and with them the length index is relatively greater.

COMPARATIVE ANATOMY.

Foot and Glands. — It is now a generally accepted fact that the ventral furrow and its included fold represents a greatly reduced pedal furrow and foot. In the Chaetodermatina all external traces of these structures have disappeared completely, but internally a gap in the ventral musculature and a thickening of the longitudinal muscles on each side of the mid ventral line and in Limifossor a well-developed pedal sinus in the head region indicate their former existence. In what appears to be the least modified species, the foot consists of a single fold, but in several other species this is accompanied on each side by a fold of almost equal height and length, and in the Neomeniidae the creeping surface is often comparatively broad and is developed into several folds. Whether one or more of these plaits exist each is bounded by a single layer of ciliated

epithelium which as a rule is continuous with the lining of the cloaca. The last named space is certainly a true mantle cavity and the plume-like branchia it contains in the Chaetodermatidae are ctenidia. On the other hand it is questionable if the folds developed in the cloacal walls, as in Alexandromenia for example, are homologous organs.

As in the Chiton embryo two sets of pedal glands exist, termed by Hubrecht ('80) the anterior and posterior pedal. The first named is a highly developed organ filling the greater part of the space between the body wall and gut in the head region. It is composed of pyriform cells whose ductules lead into the anterior end of the pedal furrow, which is usually developed into a cavity of considerable size, where they make their exit by separate intercellular openings. The posterior pedal gland is situated above and slightly to each side of the foot throughout its entire extent. Its cells are likewise pear shaped and open intercellularly into the pedal furrow.

Hypodermis and Products. — What is sometimes termed the skin consists of two main elements, the hypodermal cell layer and the overlying spiculose cuticle. In the majority of species the hypodermis consists of a single layer of cells, and exceptionally (*Paramenia palifera*, *Ichthyomenia ichthyodes*, for example) forming a more or less irregular many cell layer. Concerning the nature of the elements entering into its formation there are numerous differences judging from the accounts of the various authors, and the functions ascribed to them are equally diverse. The ordinary hypodermal cells, those responsible for the formation of the cuticle, are usually cubical or low columnar in form with round or oval nuclei imbedded in a finely granular cytoplasm pigmented in a few species (*e. g. C. nitidulum*) which blends with the overlying cuticle. In the same general situation gland cells are present in several species together with more slender elements which may perform a sensory function.

The papillae occur in all Neomeniina in which there is more than one layer of spicules imbedded in the cuticle. Generally speaking each consists of a comparatively slender stalk which is attached to the hypodermis, and on the other hand expands into a more or less globular mass in contact with the free surface of the cuticle or may even project above it. The cells composing the swollen portion are apparently filled in life with a highly spongy, possibly vacuolated protoplasm which in preserved material may shrink greatly, producing radiating pseudopodia-like processes. In *Halomenia gravida* outpouchings of the gut occur at fairly regular intervals along the dorsal side of the animal on each side of the mid line. These penetrate the somatic musculature (Plate 32,

fig. 5) and come in contact with the under surface of modified papillae, which appear to be capable of a certain amount of protrusion owing to the agency of a surrounding blood sinus. The significance of this remarkable state of affairs is very obscure; and for that matter the various functions such as excretion, touch, and pressure relations which have been ascribed to these organs as yet rest upon no direct experimental evidence. That they are the homologue of the aesthetes in the Chiton shell is a reasonable assumption, but this carries with it no trustworthy evidence regarding their office.

The spines form from one to several layers in the cuticle, and present a great variety of forms. In the Chaetodermatina spearhead-types prevail, and in the Neomeniina, where there is but one layer, this shape may likewise occur. In those species with more than one layer the usual type is needle-shape, and with it may be associated radially directed spicules usually with truncated bases.

Spicule Development. — In a number of species of the present collection, notably *Proneomenia hawaiiensis*, *Strophomenia scandens*, and *Halomenia gravida*, certain of the more important details of the formation of the spiculose investment of the body appear with unusual distinctness, and to avoid needless repetition the results are discussed once for all in the following paragraphs. Speaking first of *Proneomenia hawaiiensis*, in the earliest stages of the spicule formation, where the calcareous product is no larger than the neighboring hypodermal elements, several cells are seen to be taking part. One of somewhat larger size than the others, and with clear finely vacuolated cytoplasm and distinct granular spherical nucleus, rests underneath the base of the spine. Its general appearance is essentially like that of the cell beneath the spicules of *C. nitidulum* as figured by Wiren or the spicule forming cells in the mantle of certain species of Chitons, and is *par excellence* the lime secreting element.

Wiren is of the opinion that the basal cell is a modified wandering cell that has left the blood stream and migrated to the hypodermis. In all of the Solenogastres under discussion the wandering cells are of a granular character with no distinct cell membrane and clearly different from any of the hypodermal cells. Furthermore in the species under discussion I have never seen these plasma cells outside of the somatic muscle layer, and there are never any indications that the spicule forming elements are derived from any other source than the hypodermis.

In very early stages, perhaps from the first, the spicule is surrounded by a delicate cuticular sheath whose reaction to the ordinary stains indicates a composition unlike the material in which the spicules are imbedded. This spicule

sheath is probably formed by seven or eight cells, slender in form, indistinct in outline, with dense nuclei and attenuated bases which are imbedded in the hypodermis proper. They entirely surround the basal cell, and distally their membranes become continuous with the spicule sheath, which as Plate 36, fig. 5, shows, is thus interrupted a short distance above the base of the spine.

At a relatively early stage in the development of the spine a minute cell (Plate 36, fig. 11) may be detected between the basal cell proper and the spicule sheath. At first it appears to be connected with the deeper portions of the hypodermis by a single stalk that passes to one side of the basal cell; but in later stages such a connection disappears and the cell in question becomes closely applied to the base of the spine. It appears to be responsible for the formation of the spicule sheath immediately above it and in the following way for the cavity of the spicule itself. At first the cuticle above this small basal sheath cell is of uniform thickness and the lime salts, deposited presumably by the basal cell proper completely fill the spicule sheath, but very soon a minute knob-like elevation appears on the basal part of the sheath, and, perhaps owing to this increased thickness of the cuticle, it interferes with the deposition of calcareous material, for from this time on a cavity develops in the spine that in size and position corresponds to the cuticular knob. As the latter increases in size the spicule cavity enlarges, and when in later stages there is a decrease the cavity becomes proportionately narrowed until both finally disappear together.

In the earliest stages of its existence the long axis of the spine is at right angles to the hypodermis, but as development progresses it becomes more and more inclined until it reaches the final horizontal position. This rotation is probably due in large measure to the unequal elongation of the attached cells, while the continual advance of the free tip of the spine through the surrounding cuticle is due to the addition of new material basally. During this whole formative period and after its completion the entire spicule is migrating also toward the free surface of the body. Hubrecht and several other subsequent observers consider that this movement is caused by the continual cuticular current, so to speak, brought about by the perpetual addition of new material in contact with the hypodermis, a belief with which I concur for on any other supposition it would be difficult to account for the perfectly vertical, unbent position of the slender remnant of the matrix cells in late stages.

Until the spine has been carried outward for a distance equal to one fourth or one third the thickness of the cuticle the matrix cells retain their usual connections and generally are fairly distinct though showing more or less shrinkage

(see Plate 36). This latter feature becomes strongly marked beyond this stage and as the cells shift to a distinctly subterminal position their boundaries disappear, and in the neighborhood of the spine they become dense and fibrous. Still later they migrate to a point fully one eighth the length of the spicule from a terminal position, their attachment to the spicule sheath becomes reduced to a minute knob-like disc and all but the basal portions of the cells themselves become transformed into a slender fibrous stalk, which elongating as additions are made to the cuticular investment of the body, maintains its attachment with the spine as long as the latter remains in the cuticle. In the region of the hypodermis the outlines of the matrix cells remain distinct and unmodified with the exception of the enclosed basal cell which becomes distinctly fibrous. In certain slightly abnormal cases the stalk is sometimes unusually broad and under such circumstances the basal cell in later stages becomes distinctly fibrillar throughout its entire length, while the surrounding ensheathing cells assume rather a cuticular appearance and never so far as I have seen assume a fibrous character. In a very considerable number of cases the fibres, of unknown nature, that have developed in the original basal cell may be seen to extend beneath the level of the hypodermis, or to unite with others that may be traced for varying distances into the somatic muscles beneath. In the region of the buccal cavity, in *Proneomenia hawaiiensis*, they may be followed through spaces in the muscle layer into close proximity to the ganglionic masses bordering on the cirri. So long as the spicule remains imbedded in the cuticle the stalk is in connection with it, and appearances suggest that after the basal cell ceases to be functional as a spicule forming agent it may transmit impulses to the central nervous system as the spines and scales in the mantle of the Chitons are supposed to do.

In Halomenia, Lophomenia, Dorymenia and all of the species of Strophomenia described in the present paper this type of development prevails. In some species the matrix cells become detached from the fully formed spine, but otherwise no fundamental differences exist. Regarding the species described by other authors, Hubrecht and Heuscher agree that in *Proneomenia sluiteri* a cup of several cells clasps the base of the spicule, and Kowalevsky and Marion and to a certain extent Pruvot, and Wiren have made similar observations on other species. Through the generosity of Professor Hubrecht I have been able to examine a portion of the type of *P. sluiteri* and though the cells are not so clearly defined as in *P. hawaiiensis* there is no doubt that in both the spines follow the same course of development. Nierstrasz writes of *Cyclomenia holo-*

scricea "The spicula remain in connection with the hypodermis by thin threads, met with everywhere in the spicula" (cuticula?) and of *P. discoveryi* he states that "The spicules are formed in small accumulations in the epidermis" though one cell only is said to be active.

Thiele has consistently argued in favor of one matrix cell and it is probable that he has focussed his attention on the type of spine I am about to describe.

As noted in a preceding paragraph, there are in addition to the tangentially placed spicules in some species others that from the beginning to the close of their development are directed radially. This latter type of spine, so far as I have determined, has a mode of development completely different from the one just described. In *Strophomenia triangularis* for example as soon as it becomes clearly recognizable it rests upon what appears to be a single cell, and as long as it remains in the cuticle no additional elements put in an appearance. In the later stages the matrix cell usually becomes more cup-like closely clasping the base or side of the spine (Plate 36, fig. 18), and it may elongate to form a slender stalk but it is always unicellular. It is to be noted, however, that in this species, and perhaps in others, there are additional, radially directed spines of much larger size which appear to be formed by more than one cell though this is not certain owing to the fact that the base of each spicule is crowded against the somatic musculature.

In the Chaetodermatidae Wiren has shown that but one formative cell exists though in its early stages the spine is surrounded by three hypodermal cells which may exercise a moulding influence. From my studies I doubt this last statement. In both Chaetoderma and Limifossor the formative cell is surrounded by hypodermal elements but there is no evidence that in the development of the spine they take any active part. It thus becomes evident that there are various types of spicule formation among the Solenogastres just as there are among the Chitons, but it is a most interesting and significant fact that the most common type of Chiton-spine development (according to Plate, '01, Theil C, p. 372) is almost the precise counterpart of what exists in *P. hawaiiensis* and several other species.

Wiren is inclined to the belief that after the spicule forming cells have performed their function they become transformed into the hypodermal papillae. There is confessedly no definite evidence to substantiate such a theory, and on the other hand there are one or two facts that tend to discredit it. In the first place there is no definite relation between the number of papillae and spines; in the majority of species the latter considerably outnumber the former, notably

in Alexandromenia. And again where the spicule retains its connection with the original formative cells such a fate is out of the question. And finally a few authors, notably Heuscher, have observed the origin of these organs directly from the hypodermis. I have seen many times papillae-like elevations (Plate 36, fig. 18) such as Heuscher figures, and I am strongly of the opinion that they have no connection with the matrix cells.

Digestive Tract. — The anterior division of the alimentary canal consists of a cavity whose walls are provided with two folds (Mundleisten), usually of a horseshoe-shape that define the cirrose area where the wall is modified into numerous finger-shaped filaments. In the greater number of species this and the succeeding portions of the gut are intimately united, but in *Rhop. aglaopheniae*, Dondersia, and a few other species they are distinctly separated by a ridge covered with the spiculose cuticle investing the body generally. Thiele considers that this sensory atrium is an ectodermic invagination of the integument corresponding possibly to the Chiton snout. Accordingly where the separation is complete the true mouth is posterior to the opening of the atrial cavity, and where the latter is fused with the gut the mouth is situated behind the internal buccal ridge. In the Chaetodermatidae this anterior division is absent or is represented, as Thiele assumes, by the buccal sensory plate and possibly the semicircular groove (hallmondformige Grube).

The limits of the pharynx are difficult to define but it is generally assumed that it contains the radula and the outlets of the salivary glands. As a rule its epithelial lining is unmodified though it may be greatly folded and, in some species form papillae, which afford an outlet for the dorsal salivary glands. If an oesophagus exist it is usually not clearly differentiated from the pharynx, and in the following pages I have disregarded it.

In the Neomeniina the digestive gland or "liver" is not differentiated from the stomach or intestine. This last named organ may possibly be represented by the ciliated tract attached to the under surface of the gonad. In the Chaetodermatina the digestive gland, stomach, and intestine are clearly defined and are not essentially different from what exists in other molluscs. The cloacal chamber is probably an ectodermic invagination and a true mantle cavity. There is no evidence that it is an expanded rectum.

Muscular System. — This system has been described in a very few species though most authors refer to the more obvious features especially the nature of the body wall. This consists of an outer circular layer, resting in some species upon a layer of diagonal fibres that in turn is in contact with a system of

longitudinal bundles. In the anterior and posterior regions these are subject to various modifications, forming mouth and cloacal sphincters and dilators, and affording attachment for the gill retractors or anteriorly for the multitudinous muscles operating the forward section of the digestive tract. These last named muscles have never been fully studied in any species though they are fairly well known in *Chaetoderma nitidulum* and *Limifossor talpoideus*. As the matter rests at present there is a similarity between the various species with respect to the somatic musculature and to certain of the more conspicuous bundles elsewhere in the body, but beyond this our data are too insufficient to permit of close comparisons.

Primary Body Cavity and Septa. — The space between the alimentary canal, gonad, and body wall, the primary body cavity, reaches a varying height of development according to the species. In the Chaetodermatina it constitutes a comparatively limited pseudovascular system and in some of the Neomeniina it is likewise much reduced, but in several species it becomes much more extensive. This haemocele is divided by a horizontal septum that extends between the longitudinal fibres on each side of the body beneath the gut and so forms a ventral blood sinus. In the Neomeniina it is small, but is bounded, in every species described in the present paper, by connective-tissue fibres perforated here and there to permit of communication with the overlying blood spaces. In Chaetoderma a vertical septum separates heart, gills, and pallial complex from the remainder of the primary body cavity. It is not present in the Neomeniidae nor in Limifossor. In the last named genus there is an additional partition, essentially the same as in the Chitons, which separates the head cavity from the succeeding portions of the haemocele. It is perforated by the aorta, alimentary canal, and a pedal sinus which passes forward into close proximity to the mouth.

Circulatory and Respiratory Systems. — The heart is developed as a fold of the dorsal pericardial wall reinforced by a varying number of muscle fibres, and in some species differentiated into an auricle and ventricle. From its anterior end the aorta arises and passing dorsal to the gonad leads into a more or less definite head cavity. In the Chaetodermatina and a very few Neomeniina this vessel possesses definite walls; in the others it is part of the general lacunar network. In Limifossor a distinct connective-tissue septum bounds the head cavity posteriorly, but in the greater number of other species the blood spaces in the head region communicate directly with those surrounding the mid gut. These last named sinuses are in communication also with a ventral

median pedal sinus even though the foot be absent. In the posterior end of the body the blood is collected in a branchial sinus, if gills be present, or is conveyed to the posterior end of the heart by means of clearly defined channels in the neighborhood of the rectum. In the Neomeniina the haemoglobin is contained in the corpuscles, and in the Chaetodermatina by the plasma.

In the Chaetodermatina two plume-like respiratory organs, which spring from the anterior wall of the cloacal chamber, are in all essential respects like those of the Chitons and are doubtless true ctenidia, the space wherein they are contained being the mantle cavity. In the Neomeniina such organs are absent, though the cloacal wall may be developed into folds in some species of large size, penetrated by numerous sinuses and covered with a richly ciliated epithelium. It is believed by some investigators that such lamellae are incipient or degenerate ctenidia but there is little to support such a theory.

Apart from these organs it is probable that respiration takes place over the surface of the body, especially along the ventral furrow if such be present. It has been suggested also that the great buccal folds may possess a combined respiratory and sensory function.

Nervous System.— In the Solenogastres there is a more pronounced concentration of the nerve cells to form definite ganglionic enlargements than in the Chitons, and the nerves supplying the mantle-cavity complex arise from a more restricted section, but in the arrangement of the brain, pedal and lateral ganglia, and the labio-buccal system there is a very distinct fundamental resemblance between the two orders. In every case the brain, usually if not always bilobed, is situated on the dorsal side of the alimentary canal about the intersection of the mouth and pharynx. From its anterior face three pairs of nerves originate in the Neomeniina and innervate the buccal wall and the adjacent regions of the body. About the bases of the atrial cirri these fibres connect with accumulations of nerve cells which may be the homologue of the great ganglionic masses in contact with the brain in the Chaetodermatina. In this last named group these accessory nerve masses, ten in number in Limifossor, are connected with the brain by several nerves, and on the other hand give rise to fibres which innervate the sensory buccal plate (Mundschild). In what appears to be the most primitive condition three pairs of connectives, the pedal, lateral, and labio-buccal, take their separate origin from the brain as in the Chitons. Such a state of affairs is the rule in the Neomeniina. In *Chaetoderma erudita* these cords unite immediately before plunging into the accessory ganglionic masses attached to the brain but retain a delicate connective-tissue sheath,

and hence a perfect individuality, until they pass into the brain. In some other species of the genus, as for example *Chaetoderma nitidulum*, they fuse indistinguishably as they enter the brain. Finally in Limifossor the pedal and lateral cords fuse a comparatively long distance from the brain, and at a less remote position are completely united with the labio-buccal connective.

In every case the pedal ganglia are almost as long as the animal and hold a ventral position on each side of the pedal furrow though not always in close proximity to it. In several species commissures at fairly regular intervals have been seen uniting these cords, and equally numerous connectives have been traced to the lateral nerves which hold a more dorsal position along the sides of the body. In the posterior end of the animal the relation of these elements varies considerably in the different species. In *Proneomenia hawaiiensis*, for example, the pedal cords become reduced in calibre, and finally break up into small nerves which have not been shown to have any connection with the lateral cords though they come into the neighborhood of some of the small nerves originating from them. In *Strophomenia scandens* the last two or three latero-pedal connectives are of relatively large size and the union of the lateral and pedal ganglia is clearly established. Furthermore in several species, such as *Lepidomenia hystrix*, and *Neomenia carinata*, the posterior ends of the pedal cords terminate in ganglionic enlargements (*ganglion posterius inferius*, Wiren) united by a commissure of more than usual size situated ventral to the rectum. The posterior ends of the lateral ganglia are also frequently enlarged (*ganglion posterius superius*) and are invariably united above the rectum, thus completing in several species a circumrectal nerve ring. In the Chaetodermatidae the lateral and pedal ganglia are united, at least in the anterior end of the body, by commissures and connectives but more posteriorly these main ganglionic cords terminate in a large nerve mass, the so-called gill ganglion, continuous across the mid line above the rectum.

In what probably represents a typical condition the sublingual or buccal system, in reality the labio-buccal, holds essentially the same relations as in the Chitons. Connectives lead from the brain along the pharyngeal wall and unite with ganglia about opposite the forward end of the radula or in the neighborhood of the openings of the ventral salivary glands. These nerve masses probably represent the labial and buccal ganglia of other molluscs, and in at least one species, *Strophomenia scandens*, are united by three commissures and the subradular system. One of these commissures, the dorsal buccal, crosses the dorsal side of the pharynx, while two pass ventral to it. In *Proneomenia hawaiiensis*, where the subradular system is most highly developed, a connective arises from

the inner face of each labio-buccal ganglion and unites with a small subradular ganglion which is in close contact with a subradular organ. These two ganglia are in turn united by a subradular commissure. In the genus Chaetoderma also there is a well-defined subradular system (p. 57).

In several species of Solenogastres various authors have found what corresponds to the labio-buccal connectives and ganglia, and in most of these cases have found one commissure which is either the ventral buccal or labial. In the Neomeniidae the subradular organ is usually wanting together with the customary nerve supply; and in most species it is impossible to find more than one buccal commissure. However these nerves are usually very small and difficult to trace so that negative evidence in this case may not be entirely trustworthy.

Sense organs.— In the majority of Solenogastres a dorsal sense organ exists in the mid line in the cloacal region. In the Neomeniina it consists of a circular depression, naked or covered with a thin cuticular layer, and surrounded by spicules which in its contracted condition overarch it. When expanded by an underlying blood sinus a disc-like projection is elevated from the bottom of the depression and is raised above the surrounding spines. In the Chaetodermatina a groove, likewise overarched by spicules when contracted, is probably a homologous structure. In both families these organs are innervated by nerves from the dorsal commissure uniting the lateral nerve cords. Various functions have been assigned, but without any experimental evidence.

Thiele believes that the ventral furrow may be tactile but no sense cells have been shown to exist. In the gills on the other hand stiff hairs have been found among the cilia and are considered to be parts of sensory elements. Osphradia are unknown.

In the Chaetodermatidae the anterior sensory plate is innervated by a heavy set of nerves and probably acts as a tactile organ. Owing to the heavy cuticular covering it may act also as a digging organ, operating in a general way like a hog's snout.

In *Proneomenia hawaiiensis* a low sensory ridge encircles the atrial wall immediately within its outer opening. It is composed of high columnar cells which rest throughout their entire extent upon a rod-like mass of nerve cells. Internal to this are the usual atrial ridges (Mundleisten), of which the more external closely parallels the sensory tract just mentioned, while the inner one passes nearly around the canal at the commencement of what is probably the mouth cavity. Both are usually well-developed ciliated folds, capable, in some

species, of great distention owing to the large blood sinuses contained within. Between the ridges the lining of the atrium is developed into simple or branched, finger-like processes termed cirri. Each is composed of glandular and sensory cells frequently pigmented, and is penetrated by a slender canal traversed by a nerve fibre. Regarding the function of these organs and the ridges it is variously considered that they are gustatory, olfactory or tactile, or even respiratory. The cirri may be protruded from the opening, and this fact in connection with their glandular character has suggested that they may serve also to collect food; but judging from *Drepanomenia vampyrella* (page 79) there are times when they are inoperative in this respect.

Regarding the papillae in the hypodermis of the Neomeniina various hypotheses have been suggested. They appear to be connected with nerve fibres, and may reasonably be considered the homologue of the aesthetes in the shell of the Chitons, but up to the present time there is no proof that such is the case, nor that they are tactile, or secretory, or excretory, organs as some authors have maintained.

A subradular organ, normally located and innervated, is known to exist in a few species (page 86). In its finer details it bears a striking resemblance to its homologue in the Chitons and perhaps functions in the same way.

Coelom.— The secondary body cavity comprises the gonad, pericardium, and gonoducts whose relations have been determined in most of the known species of Solenogastres although their physiological significance remains very incomplete. The gonad, usually paired, is situated along the dorsal side of the animal between the body wall and alimentary canal. Posteriorly it is continuous, by means of two ducts, with the pericardium which in turn is in communication with the cloacal cavity by means of two canals, the coelomoducts.

So far as known all the Chaetodermatina are dioecious while the Neomeniina are hermaphroditic, and generally speaking the gonad is of the same length as the liver and therefore nearly as long as the body in members of the first named suborder. In the young the reproductive gland is paired, and in the adults with the exception of the genus Chaetoderma this condition of affairs persists, though sometimes partially obscured by the development of numerous germinal folds. In the Neomeniina the sperms arise along the outer walls of the gland while the ova, in some species surrounded by a follicle, are more inwardly placed. In the mature state the ova and spermatozoa make their way through the short, ciliated canals terminating the gonad posteriorly, and enter the pericardium from whence they pass to the outside through coelomoducts of various degrees

of complexity. In the young of some of the Neomeniina these last named canals are simple tubes of about equal calibre throughout, but in later life they become modified into a shell gland and one or more seminal receptacles. In adult Chaetodermatina these canals remain comparatively simple, and there is some evidence that they function as excretory organs as well as genital ducts.

In every case the coelomoducts originate from the hinder wall of the pericardium as comparatively small, ciliated tubes which pass anteriorly to about the level of the forward wall of the pericardium where they make a sharp bend and join the so-called shell gland in the Neomeniina. At the intersection of these two divisions from one to twenty-five vesicular appendages are usually attached, which have usually been considered seminal receptacles though the arrangement of the sperms in a few species indicate that for at least a part of the breeding season they may function as seminal vesicles. As the distal or ventral portions of the coelomoducts usually unite before entering the cloaca the shell gland which they form is a bicornuate, comparatively swollen structure with excessively thick walls and contracted lumen. It is reasonably certain that this organ functions as a nidamental gland, forming possibly an albumenous envelope before the egg passes to the exterior.

In intimate connection with the genital apparatus just described there are a number of problematical organs which in some cases at least appear to have some rôle to play in the reproductive process. These include the genital spicula or penes such as occur in *Neomenia carinata*, *Dorymenia acuminata*, *Pararhopalia pruvoti*, *Stylomenia salvatori*, and several other species. These are either relatively large calcareous paired spines, which ordinarily are concealed in sheaths formed as anteriorly directed diverticula of the cloacal wall, provided with protractor and retractor muscles and in some cases with a gland, or similar diverticula, may conceal numerous spines of much smaller size. While the function of these organs is unknown it is reasonable to believe, with several authors, that they are excitants and possibly in a few species they may serve to attach the animals *in coitu*.

The preanal gland (Hubrecht), which is attached to the anterior face of the cloacal wall in *Proneomenia sluiteri*, and opens at the end of the pedal furrow or right and left under the cloaca, may be associated in some way with the reproductive process.

Physiology.— Several authors, notably Wiren, have called attention to the striking resemblance between the Chiton kidney and the coelomoducts of certain species of Chaetoderma; and again the presence of crystals has been

noted in these same organs. It thus becomes very probable that they aid in the removal of waste matters, and as noted on page 169 the fact that the male and female glands are identical in form and structure indicates that they play no especially important part in the egg-laying process, merely conveying the ova from the pericardium to the exterior. In the Neomeniina there are certain indications that the coelomoducts do not serve as kidneys, and the fact that they are non-glandular in immature individuals points also to their non-excretory character.

In other parts of the body of several other species of Solenogastres there are organs of widely different character which are believed by various authors to hold the office of excretory organs. These include a number of structures which are in close proximity to the cloacal wall or are modifications of it. Among them are anal, preanal, or byssus (improbable) glands probably not in all cases homologous and evidently in some species playing a part in the process of reproduction, especially where they are muscular, vesicular invaginations of the cloacal wall. Pruvot described a mass of spongy, glandular cells in *Myzomenia banyulensis*, forming a low elevation on the floor of the cloacal cavity, and containing yellow granules similar to others of larger size in the free cells of the underlying tissue. The supposition is that these last named elements are leucocytes, which, collecting materials from the blood, pass them to the cloacal wall from whence they are voided to the exterior. Thiele states also that in *Proneomenia neapolitana* there is an accumulation of cells irregular in form, forming a preanal gland between the hypodermis and the somatic musculature. Similar elements are attached to the cloacal wall, the rectum, and coelomoducts, and others of somewhat like character are found in the intestinal sinus. Their resemblance to chlorogogue cells is marked, and for this reason chiefly they are believed to exercise the same function. Heath also has noted the presence of certain cells, along the ventral sinus of *Limifossor talpoideus*, whose shape and granular contents suggest the connective-tissue, concrement-bearing elements in the Chitons and other molluses as noted by Brock. The papillae have been looked upon as glandular bodies by several authors and of these a few consider them to be excretory. On the other hand they may function as organs of special sense (see page 40).

Respiration to a certain extent probably occurs over the general surface of the body, especially in those species with thin cuticle or where the cuticle is provided with blood sinuses. The ventral groove, as several authors have suggested, certainly permits the interchange of gases. The walls of the atrial cavity, especially the cirri and ciliated folds are believed also to take a share in

the process, and it has even been suggested that the entire stomach-intestine may be active. In the Chaetodermatina definite ctenidia perform the respiratory function, while in the Neomeniina the thin walls of the cloacal cavity, often thrown into folds, sometimes of enormous size, and in contact with extensive blood sinuses, are undoubted active agents in this respect.

In some species, such as in Alexandromenia the atrial ridges are of large size and their superficial extent is increased by the development of secondary folds and papillae. As these are penetrated by large blood sinuses it is probable that they act to a certain extent as respiratory organs though it is doubtful if this is their chief duty. The cirri on the other hand never, or very rarely, contain blood spaces and are very probably special sense organs.

As the functions ascribed to the various sense organs, real or supposed, have been tested experimentally in a few cases only, it is not surprising that the opinions of authors differ widely. Considering first the sense of touch it is probable that it is located over the general body surface, for living specimens of *Chaetoderma erudita* and *C. montereyensis* respond to mechanical stimuli applied at any point. A number of investigators have noted the presence of nerves in contact with the hypodermis in other species and Wiren has traced some of them into the deeper portions of the cuticle where they are supposed to function in the sense of touch. In those species with thin cuticle and freely projecting spines it is likewise supposed that the latter serve as tactile organs. This same activity is ascribed a'so by Thiele to sense cells which he has detected in the foot of certain Neomeniidae (*Neomenia grandis, Proneomenia vagans*). Of the various activities which have been connected with the much discussed papillae of the hypodermis is the ability to distinguish vibrations, amount of water pressure, or more generalized stimuli affecting the tactile sense. It is to be noted, however, that on the other hand these organs are said by several authors to be strictly glandular. A remarkable problematical relation of some of the papillae, considerably modified, to the anterior coecum of the stomach-intestine in *Halomenia gravida* (p. 147) is difficult to explain on any hypothesis.

From experiments Wiren finds the gills of Chaetoderma to be very sensitive, and considers that the stiff hairs situated among the cilia are probably tactile. The buccal papillae are said by Heuscher to be organs of touch; they are certainly not universally, if ever, food collecting organs. In close connection with the anterior border of the mouth of a few species in a living condition Pruvot, and Kowalevsky and Marion have detected sensory hairs, that in some species are attached to elevations, apparently the homologue of the sensory ridge, that

I have found paralleling to some extent the outer buccal sensory fold (p. 84). Pruvot has noted that as some of these animals progress they move the anterior end of the body from side to side, and appear to be using the organs in question to detect the character of their surroundings, so that they may be tactile. In Ichthyomenia there are many pits, apparently ciliated, in the anterior end of the body. These are probably sense organs, but of unknown function.

The buccal sensory plate in the Chaetodermatidae with its enormous nerve supply may very probably function also as a tactile organ as Wiren and others have assumed, but it is to be noted that while this structure takes an active part in the excavation of burrows it is probable that it serves to detect the presence of food. At all events the alimentary canal of these animals is singularly free from inorganic materials, and in the absence of any other well-defined organs in or near the buccal cavity it is not improbable that the plate acts as an olfactory or more than usually delicate tactile organ. These same activities or possibly the sense of taste have been assigned to the frontal sense organ noted in the preceding paragraph.

The dorso-terminal groove in the Chaetodermatidae and its homologue in the Neomeniidae is usually considered to be an organ of special sense, Heuscher alone alleging the contrary owing to the fact that the depression in *Proneomenia sluiteri* was filled with detritus. This condition is not infrequently encountered in animals which have been excavated from the material in a dredge, but it is certainly not a normal state of affairs. Concerning its function we have absolutely no positive evidence. It is reported by Pruvot that it may hold the same office as the frontal sense organ though the belief appears to rest upon nothing more tangible than a certain similarity of structure.

CLASSIFICATION.

While the modification, by Nierstrasz, of Simroth's scheme of classification doubtless fails of necessity to indicate accurately the phylogenetic relationships of the Solenogastres it has the virtue of being more convenient than any other now in use and hence has been adopted in large measure. The family name Parameniidae must be discontinued. Cockerell ('03) has shown that Pruvot's genus Paramenia is preoccupied and has proposed the name Pruvotina, hence in the following table I have used a new family name Pruvotiniidae. The family

Lepidomeniidae Nstr. containing Dondersia must retain Simroth's name Dondersiidae.

As has been noted by other authors the genus Proneomenia as created by Hubrecht, has been much enlarged to include a number of species some of which probably belong to other genera. *Proneomenia weberi* appears to be very closely related to *Dorymenia acuta* and may in reality belong to Dorymenia.

In the genus Strophomenia the long pharynx, the papillae and the numerous seminal receptacles are so characteristic and similar in the species of the present collection that I have no hesitancy in placing all in the same genus. Pruvot's material was poorly preserved, as he states, and under such circumstances the peculiar condition of the ventral salivary glands is readily explained as I know from experience. The radula sac is likewise incorrectly placed, being much too far forward. Evidently in Pruvot's species all traces of this organ have disappeared. With this revision the species are quite similar. It is probable that *Rhopalomenia indica* Nierstrasz belongs to this genus.

Order Aplacophora v. Ihering.

Suborder. I. Chaetodermatina Simroth.
Spiculose integument continuous all around the body.
Chaetodermatidae, p. 42.

Suborder II. Neomeniina Simroth.
Spiculose integument interrupted beneath by a longitudinal ventral furrow.
Neomeniidae, p. 44.
Proneomeniidae, p. 45.
Pruvotiniidae, p. 47.
Dondersiidae, p. 48.

CHAETODERMATIDAE Simroth.

Opening of mouth and anal chamber terminal. Body with more or less sharply marked regions. Ventral furrow and fold lacking. Two highly developed plume-like gills. Radula distichous, polyserial or strongly reduced to a large unpaired cuticular tooth. The mid-gut possesses, in most cases, a well-developed digestive gland. Copulatory apparatus lacking. Coelomoducts remain separate. Cuticle thin, spicules flat, often needle-form, but solid. Inhabit bottom ooze.

Chaetoderma Loven, 1845.

Body vermiform, without ventral groove; mouth and anal chamber terminal. Two gills. Sexes separate. Radula reduced to conical peg. Type of genus *C. nitidulum*.

C. argentea, sp. nov.

Length 24 mm. by 1.6 and 2.6 mm. through the metathorax and preabdomen respectively. Silvery white. Spines, in side view, usually bent. Alaska. (p. 62.)

C. attenuata, sp. nov.

Body long and slender, measuring 61 mm. in length by 1.5 through the metathorax and 2.7 through the preabdomen. Buccal plate relatively small. Alaska. (p. 55.)

C. californica, sp. nov.

Body measuring 24 mm. in length by 1.6 mm. greatest diameter. Larger spines with expanded bases. California. (p. 64.)

C. crudita, sp. nov.

Average length, in preserved state, 27 mm. by 2.5 mm. average thickness of preabdomen. Buccal plate deeply cleft by mouth opening. Brain of large size. Alaska. (p. 59.)

C. hawaiiensis, sp. nov.

Body slender, measuring 12–19 mm. in length by 0.5–0.6 mm. greatest thickness. Buccal plate broadly elliptical, perforated in centre by mouth. Hawaii. (p. 49.)

C. japonica, sp. nov.

Length 17 mm. by 1.5 mm. greatest thickness, buccal plate shield-shape, perforated by mouth opening. Japan. (p. 67.)

C. montereyensis, sp. nov.

Length 45 mm. by 3 mm. greatest diameter. Buccal plate unusually large. Tooth stout. Monterey Bay, California. (p. 61.)

C. nanula, sp. nov.

Body small, comparatively stout, measuring 9 mm. in length by 1.4 mm. greatest diameter. Spines keeled and of heavy appearance. California. (p. 66.)

C. robusta, sp. nov.

Body heavy, measuring 60 mm. long by 3.5 and 4.7 mm. through the meta-

thorax and preabdomen respectively. Buccal plate shield-shape. Largest spines relatively slender without definite keel. Alaska. (p. 68.)

C. scabra, sp. nov.

Small, measuring 12 mm. in length by 2 mm. greatest diameter. Body wall relatively thin. Brownish, becoming olive-green in region of digestive gland. Monterey Bay, California (p. 63.)

Limifossor Heath, 1904.

Body short. Radula very large, distichous, with twenty-eight transverse rows in *L. talpoideus* (about the same number in *L. fratula*). Dorsal salivary glands present. Stomach and digestive gland well developed, and distinct from intestine. Type of genus, *L. talpoideus*.

L. fratula, sp. nov.

Slaty gray with yellowish cast. Spines from middle of body 0.5 mm. long. Length index 1.3–4.7. California. (p. 72.)

L. talpoideus.

Slaty gray in color. Spines, from all parts of the body, 0.02–0.38 mm. in length. Length index 1–6. Alaska. (p. 69.)

NEOMENIIDAE Simroth.

Body compressed, more or less crescent-shaped, without distinct divisions. Index 7 at most. Opening of atrium ventral, of the anal chamber ventral or terminal. Ventral furrow present, usually with several folds. Cuticle sometimes comparatively thick, spines mostly needle-like, flat, grooved, or hollow. A circlet of gills in the anal chamber. Radula and salivary glands usually lacking. Epidermal papillae, of simple structure, usually present. Fore gut protrusible. Coelomoducts separate or united to form shell gland or copulatory organ. Digestive gland lacking. Penial spines usually present. Free, creeping about over bottom.

Drepanomenia, gen. nov.

Body short and thick. Hollow needle-like spines with truncated bases; slender stalked papillae. Ventral salivary glands long and tubular. Coelomoducts simple, without appendages. No copulatory apparatus. Type of genus *D. rampyrella*, sp. nov.

With characters of the genus. Hawaii. (p. 77.)

Pachymenia, gen. nov.

Body stout, measuring 27 by 4.5 mm. One layer of awl-like spines, papillae multicellular with broad bases, posteriorly ill defined. Pharynx very large and muscular with numerous glands some of which open by one pair of ducts at forward border of pharynx. Dorsal and ventral limbs of coelomoducts provided with numerous glands. One pair of small seminal receptacles. Cloacal wall covered with glands except region of branchial folds. No copulatory spines. Type of genus

P. abyssorum, sp. nov.

With characters of the genus. California. (p. 72.)

PRONEOMENIIDAE Simroth.

Worm-like. Radula distichous or polystichous, sometimes lacking. Salivary glands tubular, lobed or lacking. Cuticle thick, spicules mostly needle-like in several layers. Epidermal papillae present. Gills usually lacking. Coelomoducts usually united into shell gland, sometimes separated. Copulatory apparatus may be present. Free living, partly or entirely parasitic.

Proneomenia Hubrecht, 1880.

Body elongated, vermiform, the length 9–50 times the diameter. Cloaca opening ventral. Foot present, the groove passing into the cloaca. Cuticle thick with crowded spicules. No gills. Radula multidentate. Two salivary glands. Copulatory organs present or absent. Type of genus, *P. sluiteri*.

P. hawaiiensis, sp. nov.

Length 36 by 2 mm. Dorsal and ventral salivary glands. Radula with 38–40 teeth in each transverse row. One pair of seminal receptacles. No copulatory organs. Hawaii. (p. 82.)

P. insularis, sp. nov.

Anterior end similar to the foregoing species (posterior end missing). One pair long, tubular salivary glands. Radula polystichous with 28 transverse rows. Hawaii. (p. 90.)

Driomenia, gen. nov.

Measurement 9 by 1 mm. Cuticle thick, papillae present, spines needle-shaped, slightly curved. Atrium separate from mouth opening, no radula, one pair globular ventral salivary glands. Antero-lateral pericardial wall prolonged

into a pair of horn-like pouches. One pair seminal receptacles. No copulatory spines. Gills absent. Type of genus

D. pacifica, sp. nov.

With characters of the genus. Japan. (p. 93.)

Dorymenia, gen. nov.

Vermiform, body terminating posteriorly in a finger-shaped elongation. Radula polystichous, with 48–51 longitudinal rows of 22 teeth each. One pair of seminal receptacles. A pair of long copulation spicules closely associated with a pair of globular coeca likewise opening separately into the cloaca. Type of genus

D. acuta, sp. nov.

With the characters of the genus. California. (p. 95.)

Strophomenia Pruvot, 1899.

Body elongated, cylindrical, the thick cuticle penetrated by acicular spicules and closely crowded vesicular papillae; radula and salivary ducts, caudal sense organ sometimes absent (?); two distinct genital openings into the cloaca. Type of genus, *S. lacazei*.

S. farcimen, sp. nov.

Length 18 by 2 mm. Papillae smal', closely crowded. Radula with 15 transverse rows of 24–28 teeth. 19 seminal receptacles. Japan. (p. 119.)

S. ophidiana, sp. nov.

Length 43 by 2.5 mm. Papillae fairly numerous. No radula. 23 small seminal receptacles. Japan. (p. 112.)

S. regularis, sp. nov.

Anterior end missing. Papillae small, closely crowded. 12 seminal receptacles. Japan. (p. 116.)

S. scandens, sp. nov.

Length 32–39 by 1.6–2.1 mm. diamter. Papillae crowded. No radula. 15–18 seminal receptacles. Hawaii. (p. 106.)

S. spinosa, sp. nov.

Length 28 by 1 mm. Papillae few. Radula small, monoserial or biserial with 8 transverse rows. 12–31 seminal receptacles. Japan. (p. 122.)

S. triangularis, sp. nov.

Length 12 mm. by 1.6 mm. diameter. Triangular in cross section. Radula

distichous, apparently comb-like with 16 cusps in each row. Seminal receptacles 10–12. Japan. (p. 125.)

PRUVOTINIIDAE, nom. nov.

Worm-like. Cuticle, as a rule, thick; spines as in Proneomeniidae or hook-like. Epidermal papillae present or absent. Radula distichous, simple or double comb-form, or lacking. Salivary glands globular, lobed or tubular. Gill folds present. Coelomoducts united to form unpaired shell gland. Copulatory apparatus may be present. Ventral furrow and fold present. Free or living on coral, etc.

Lophomenia gen. nov.

With dorsal keel; length 24 mm., diameter 1.5 mm., 3 ventral folds. Cuticle thick, with numerous needle-like spines in several layers; papillae few, club-shaped. Radula distichous, 20 transverse rows. Dorsal salivary gland large; ventral globular. 2 seminal receptacles, 2 bundles of many copulatory spines. Type of genus

L. spiralis, sp. nov.

With characters of the genus. Hawaii. (p. 128.)

Alexandromenia, gen. nov.

Body relatively short and thick, length 25–32 mm. by 3.5–5 mm. diameter. Spicules small needle-like associated with larger radially directed ones. Papillae very large, multinucleate. Foot, 5–9 folds. Gill folds 20–40. Numerous pharyngeal glands and enormous lobulated glands opening on the sides of the pharynx. Radula monoserial. 1 pair seminal receptacles. Type of genus

A. agassizi, sp. nov.

Posterior end truncated, gills exposed. Monoserial radula with slightly curved rectangular teeth. 40 gill folds. California. (p. 133.)

A. valida, sp. nov.

Posterior end rounded, cloaca opening ventral. Teeth with two horn-like projections. 20 gill folds. California. (p. 142.)

Halomenia, gen nov.

Body short, length index 7:1. Spicules needle-like. Papillae large, in places resting upon diverticula of the mid gut. 2 ventral folds. Gills 26–30. Radula distichous. 1 pair seminal receptacles or vesicles. Type of genus

H. gravida, sp. nov.

With the characters of the genus. Kurile Islands. (p. 146.)

DONDERSIIDAE Simroth.

Body often worm-like. Cuticle thin; spines flat and solid. Papillae lacking. Radula distichous, monoserial or lacking. Salivary glands globular, sac- or tube-like. Gill folds lacking. Coelomoducts united or separate. Copulatory apparatus may be present. Ventral fold and furrow may be absent. Living free, or on corals, etc.

Herpomenia, gen. nov.

Length 11–18 mm. by 0.6–0.9 mm. Foot smoothed out, ciliated. Ventral salivary glands very large, encircling the thick walled very muscular pharynx. Radula lacking. 1 pair seminal receptacles. Shell gland almost globular. Type of genus

H. platypoda, sp. nov.

With the characters of the genus. Aleutian Ids., Alaska. (p. 151.)

Dondersia Hubrecht, 1888.

Body long, length index 10–48. 1 ventral fold. Spicula needle- or spatula-shaped, flat. Cuticle very thin, no papillae. Dorso-terminal sense knots present. 1 pair of short ventral salivary glands, which unite before opening out into the pharynx. Radula small, monoserial or biserial. Mouth cavity and pharynx opening separated from each other. No copulation spicula. Type of genus, *D. festiva*.

D. californica, sp. nov.

Dorsal salivary glands very scant; ventral small. Radula with at least 12 pairs of teeth. Immature. California. (p. 155.)

Ichthyomenia Pilsbry, 1898.

Body cylindric-conic, broader behind, narrowed in front. Cloaca opening a terminal transverse slit, a prominence in front of it. Foot groove and foot present, disappearing posteriorly. Cuticle not papillose, the ventral spicules leaf-shaped, the rest scale-like, imbricating. No gills. Radula well developed or rudimentary, with apparently two rows of teeth. Length 5 to 13 times the breadth. Type of genus, *I. ichthyodes*.

I. porosa, sp. nov.

Body pale yellowish white, 16 mm. long by 1.2 mm. thick. Scales fish-like and club-shaped. Upwards of 50 sensory pits in the anterior end. No radula. California coast. (p. 159.)

DESCRIPTION OF SPECIES.

Chaetoderma hawaiiensis, sp. nov.

Two specimens of this species were dredged in the vicinity of Kauai Island. The first came from the western end (Sta. 4130) at a depth of 283–309 fath.; the second from the northern extremity, Mokuaeae Islet (Sta. 3992), at a depth of 528 fath.

The first specimen was found in a mass of polyps of Epizoanthus (Plate 2, fig. 3) elevated at least a foot above the bottom, and densely matted together in such a manner as to preclude the possibility of accidental lodgment. The second individual was found by Dr. W. K. Fisher among the spines of a species of starfish (*Odinia pacifica* Fisher) also in such a position that it could scarcely be due to accidental shifting. There is no especial reason for considering this species a parasitic form nor indeed a commensal, for the food in the alimentary canal consisted of small quantities of plant spores, sponge spicules, and organic debris such as is ordinarily found in those species that burrow in the ooze. It seems more probable that it, like *Chaetoderma nitidulum*, as described by Wiren, may leave its burrow to crawl about on the bottom, or as in the present case even on the bodies of other animals.

In its external features this species displays the usual characteristics of other members of the family. The body including the globular and apparently non-retractile prothorax, itself about 2 mm. in length, is 12 mm. long. Immediately behind the swollen part of the prothorax the diameter of the body is 0.65 mm., and this continues with little change through the anterior half of the animal. Beyond this point the calibre gradually increases to $1\frac{1}{3}$ mm. in the neighborhood of the cloaca, beyond which a slight decrease occurs that continues to the end of the body. In the other specimen the size of the prothorax is the same, but the length of the metathorax (19 mm.; diameter 0.5 mm.) and the abdomen (7 mm.; diameter 1 mm.) is considerably greater and bears witness to the futility of using the length index in the discrimination of some species.

The color of both specimens is a slaty gray, though this is usually obscured by an inorganic incrustation covering the body generally. In the region of the metathorax the larger spines are completely hidden in a granular deposit that gives this part of the animal a brick-red shade. The same substance, in one case black in color, is present in several other species of Chaetodermatidae in my possession, and may perhaps be an excretory product thrown out from the coelomoducts.

The cuticular plate covering the frontal sense organ is almost circular in outline and is elevated above the general surface of the prothorax. This is especially the case with the lateral portions which assume the form of pronounced folds decreasing in height as the centre of the organ is approached. The boundary between the cuticle and the underlying epithelial cells is not sharp and the outlines of the cells themselves are not clearly visible. The greater number appear to be sensory elements and are distinguished by their relatively slender appearance (the diameter being to the height as one to four) and by darkly staining elongated nuclei placed in the basal half of the cell. Among these are a few cells of the same height, but of greater diameter, which contain spherical centrally placed nuclei with a small amount of chromatin. Great numbers of ganglion cells are situated in immediate contact with this sensory plate, and some of the more deeply seated clearly connect with nerves passing out from the precerebral ganglia (as I have termed the great accumulations of ganglion cells in contact with the brain in the Chaetodermatidae), and on the other hand originate fibres that pass down to the frontal organ (Plate 28, fig. 1). A very few small pyriform gland cells, staining almost black in haematoxylin, extend from the midst of the ganglion cells to the sense organ where they probably open to the surface. Large numbers of muscle fibres attach also to the sensory epithelium and at several points there are indications that they pass between the hypodermal cells and connect directly with the overlying cuticle.

The hypodermis is practically the same as in other species and not particularly favorable for the solution of any of the several problems connected with it. Its cells differ considerably in form and appearance. In the swollen part of the prothorax they are slightly higher than broad; in the metathorax the reverse is true; while in the abdominal region the height is about twice the diameter. Everywhere their boundaries are indistinct, and thus unlike the sharply defined central nuclei. Here and there are more slender elements with elongated darkly staining nuclei, and somewhat more numerous are the basal cells in contact with the base of the overlying spicules. These latter cells vary widely in general appearance from very small compact elements to others large, globular, and much vacuolated, owing to different stages of development and probably to some extent to mechanical compression. No pigment cells exist, nor wandering cells nor other elements that are sufficiently different from the usual constituents to be placed in a separate catagory.

The spicules are of the usual spearhead shape, and form a continuous series of increasing size, from those of the prothorax with a length of .0275 mm.

to others on the postabdomen .225 mm. long. Plate 37, fig. 12, gives an accurate idea of the usual type of spine, these being from the middle of the metathorax.

The mouth opening is situated about the centre of the frontal sense organ and is remarkable for its minuteness. From here to the region of the radula the canal is relatively small, not exceeding one seventh of the greatest diameter of the prothorax. It is invested by a thin layer of muscles and is attached also to a considerable number of scattered fibres that pass outward and are inserted in the body wall. Ganglion cells arranged in groups as in the Neomeniidae are also fastened to the buccal mass. The epithelial lining consists of high columnar cells with basal nuclei imbedded in moderately dense cytoplasm, that more distally becomes filled with a finely granular colorless secretion. In one specimen particles of a golden yellow color occurred in, or between, some of these elements, but whether they were developed *in situ*, or had been produced by cells more externally placed, it is impossible to determine.

While in one specimen the digestive tract continues of about the same calibre throughout, the other expands widely in the region of the radula, and at the anterior end of this enlargement a circular fold is present that is probably homologous with the proboscis of Drepanomenia, for example. In one individual this swollen section is almost completely filled with diatoms, plant spores, sponge spicules, and organic remains some of which appear to have been mixed with some viscous secretion and moulded into globular masses.

From a point corresponding to the hinder border of the globular part of the prothorax to the anterior end of the preabdomen, the wall of the digestive tract is relatively thin due to the scarcity of muscle fibres and the lowness of the epithelial cells. The latter are columnar elements of medium height with spherical basal nuclei and an abundance of a finely granular, light yellow substance filling the entire distal half. At various points throughout the prothorax and metathorax this substance is in the act of escaping in the form of droplets constricted from the cell, and all stages exist between this and the development of a finely granular secretion filling the canal. Cells freed of this secretion are cubical in form and are usually relatively dense. Cleared specimens show that while in this part of the gut true pouches do not exist the canal is by no means entirely straight, wrinkles and folds occurring throughout, though they lack the definiteness and regularity of the dilations in the Neomeniidae.

At the level of the front end of the gonad the development of digestive fluids becomes relegated to a set of cells that form a large diverticulum extending to the hind end of the body. In this digestive gland, judging from the material

in hand, two distinct kinds of material are secreted, but in widely differing quantities according to the locality. The cells attached to the gonad are usually more or less pyriform with comparatively small, dense almost homogeneous nuclei placed basally, while the remaining protoplasm is closely packed with innumerable granules. By far the greater number of these are spherical and of yellow or slightly greenish yellow tint. They are liberated, as is the secretion in the more anterior parts of the gut, by the constriction of droplets from the distal end, and may be seen undergoing disintegration and solution in many different places. Among the granules of this character are others in the form of small particles of a distinct pink or violet color after treatment with haematoxylin. They have every appearance of being an end product and not a stage in the development of the more abundant secretion.

Elsewhere in the gland the cells are of looser texture, the basal nuclei are relatively larger and granular and many if not all contain the two species of secretion just described. Generally the yellowish product is scant in amount, while in many cells the violet tinted substance accumulates in spherical or elliptical masses, surrounded by a vacuole in preserved specimens, that almost fills the cell. These secretory products are passed out entire, and in a single section as many as twenty-five may hold positions in the lumen of the gland. Making their way forward many if not all pass into the intestine, and here may be seen in various stages of solution, forming at first a vacuolated product that before dissolving completely transforms into a finely granular material of maroon color after treatment with haematoxylin.

The cells of the intestine are cubical in form and in front of the pericardium show signs of slight glandular activity. Behind this point this phase of activity disappears, and cilia become developed and continue to the opening into the cloacal cavity.

The large size of the ganglia and the abundance of the nerve cells that envelop them and also the sharpness of even the smaller nerves renders it possible without much effort to gain a very clear idea of the nervous system of this species (see Plate 7, fig. 2). As is there shown the brain, located some distance above the digestive tract, is distinctly enveloped in a delicate connective-tissue sheath and is clearly bilobed in form though its outlines are somewhat obscured by great masses of ganglion cells (forming the precerebral ganglia) attached chiefly to its lateral and anterior surface. A considerable number of delicate fibres, passing out from the brain, attach to these ganglionic bodies which in turn are connected with large numbers of nerve fibres that pass chiefly to the walls of the mouth and the frontal sense organ.

This part of the nervous system is thus essentially as we find it in other Solenogastres. In *Proneomenia hawaiiensis*, for example, the supraoesophageal ganglia are connected with several nerves some of which unite with groups of ganglion cells attached to the bases of the cirri, and from these again other nerves pass to the digestive tract and probably to the body wall. In Chaetoderma the chief difference is that the nerves uniting the brain and precerebral ganglia are very short.

In the present species the pedal and lateral connectives unite immediately before plunging through the precerebral ganglia, and as Plate 7, fig. 2 shows the labio-buccal cord unites with them before the brain is reached. This same condition of affairs exists also in two species of this genus taken in Alaska, though much more obscured than in the present species. At the posterior end of the prothorax the pedal and lateral cords that have gradually approached each other actually come in contact and in one specimen even fuse for a short distance and lose the usual sheath of ganglion cells. Anterior to this point two pedal commissures exist, but until the hindmost part of the body is reached no farther trace of such nerves has been found. On the other hand latero-pedal connectives are present throughout the entire length of the animal.

The relations of the labio-buccal ganglia are represented in Plate 7, fig. 2. The non-ganglionic connectives imbedded in the pharyngeal wall unite with the superficially attached ganglia, that are also united by a commissure passing behind the median tooth. In front of the radula there are connectives giving rise to nerves passing dorsally to what is probably the subradular organ and in addition attaching to a ganglionic mass in the mid line. As this part of the nervous system appears with greater distinctness in *C. attenuata* it is more fully described in that connection.

Throughout the entire metathorax the lateral and pedal cords pursue their course almost in contact, here and there giving rise to nerves that soon disappear, and finally join in the extreme posterior end of the body. Shortly after their union they are connected by a heavy ganglionic commissure passing dorsal to the intestine. In the mid line it develops a single nerve that makes its way into the tissue of the rectum, while on the dorsal side four fibres originate, two of which pass at once into the gills while the others attach to the inner side of the cloacal epithelium, and branching repeatedly supply this membrane and the dorsal body wall and a well-marked fold of the hypodermis to be described presently. At the junction of the latero-pedal cord and the commissure a nerve arises that passes backward and appears to supply the ventral body wall of the cloacal region.

Owing to the debris encrusting the posterior end of the body it is impossible to determine the position of the dorsal sensory groove in entire specimens. In sections it is seen to occupy the usual position, that is from the extreme hinder end of the animal forward to a point almost immediately above the level of the anal opening. As is represented Plate 6, fig. 8, it consists of a relatively deep fold of the hypodermis, that anteriorly rapidly disappears but is continuous with a ridge-like elevation in the mid dorsal line extending for a short distance more anteriorly. Some of the spines of the immediate neighborhood are of comparatively small size and overarch the depression, which is also covered by a thin continuation of the cuticle investing the body.

The cells of this organ consist of those common to the hypodermis, and others which are much more slender and compact with spindle-shaped nuclei usually subcentrally placed. The latter elements are probably sensory and connect with small groups of ganglion cells holding positions immediately beneath the circular somatic muscles in the neighborhood of the organ, and on the other hand are undoubtedly related with nerves from the branchial ganglia. That this is a definite sense organ and the homologue of the dorsal organ of the Neomeniidae, as maintained by various authors, there is little doubt, but there is nothing that more definitely establishes its function.

The gonad extends from the front end of the metathorax to the pericardium with which it is united by two short and comparatively wide ducts. Both specimens were sexually mature males and considerable quantities of spermatozoa occupied positions in the pericardial cavity, and at various points in the coelomoducts. These last mentioned organs arise from the postero-lateral borders of the pericardial chamber in the form of clearly defined tubes, whose cells are nearly cubical in form and support an abundance of large cilia. Bending sharply inward each becomes continuous with a canal, of much larger size and different structure, that after extending forward for a short distance pursues an irregular course opening symmetrically on each side of the rectum. The large non-ciliated portion of the ducts is composed of rather low cells with well-defined, basally placed nuclei, in which the chromatin exists in the form of a moderate number of sharply defined granules. In the more distal part of each cell is a sharply defined vacuole, in which are one or two light greenish yellow bodies, having the appearance of concrements such as occur in the kidneys of several molluscs. At various places these are in the act of escaping through the ruptured or dissolved end of the cell or having become free are undergoing a process of solution. Such an appearance in the kidney of other molluscs would not in any way appear unusual,

and leads to the irresistible conclusion that here the coelomoducts are not only morphologically related to the renal organs in the Chitons or other molluscs, but physiologically also as Wiren first clearly stated.

Chaetoderma attenuata, sp. nov.

Eight specimens of this species were dredged near the southern limit of Alaska, buried in glacial mud brought down chiefly by the Stikine River. One from Kasaan Bay (Sta. 4244) occurred in green mud at a depth of 50–54 fathoms; five opposite the mouth of the Stikine River (Sta. 4250) were in the same habitat at a depth of 61–66 faths.; while two in the waters of Stephens Passage (Sta. 4252) were buried in gray mud at a depth of 198–201 faths. Their appearance in life, Plate 4, fig. 3, answers closely for preserved material. The type specimen measured 45 mm. in length by 1.7 mm. through the metatherax, and 2.6 mm. through the abdomen. The color of alcoholic material, which is the same as the living save for the pinkish tinge due to haemaglobin in the head and gill region, is almost white with a tinge of yellow, becoming grayish where the liver is located.

The body wall, including muscular, hypodermal, and cuticular layers, is of median thickness and is typically located, but in specimens killed in vom Rath's fluid certain elements appear that have not been fully described, though they probably occur in all species of the genus. These are the so-called giant cells (Riesenzellen Wiren) which in ordinary material present the form of empty vesicles with the nucleus imbedded in the wall. In life this cavity is filled with a secretion, that after treatment with fluids containing osmic acid, is granular as Wiren has remarked. In favorable situations it may readily be seen that fibres, muscular at least in part, extend from the somatic musculature and penetrating the hypodermal layer attach to the sides of these cells (Plate 25, fig. 7). Appearances suggest that the secretion, upon the contraction of the fibres, is forced into the neighboring lacunae, but in no case has this been actually observed though proximally the cell may be produced into a comparatively slender, short stalk. Distally the cells are usually in close contact with the free surface of the cuticle and present a sharply defined rounded appearance. Posteriorly these elements become somewhat less numerous and of smaller size. In alcoholic killed material the fibres may be distinguished, but their attachment to the cell body is very indistinct.

Wiren ('92) states that these giant cells are not sharply differentiated from the basal matrix cells of the spicules, but this refers, so far as I am able to judge,

merely to their form as the spicule mother cells do not contain any clearly defined granular secretion. On the other hand the matrix cells shade much more perfectly into the cubical elements that probably form the cuticle.

The mouth, placed in a cleft on the dorsal side of the buccal plate, opens into a tube whose form and general appearance are represented (Plate 25, fig. 1). The lining epithelium consists of the usual high columnar cells produced into several irregular longitudinal folds, through which the outlets of the buccal glands make their way. These last named organs are comparatively abundant, especially on the ventral side of the pharynx, and extend from the region of the brain to the radula.

A subradular organ certainly exists in this and several other species, if position and innervation be any criterion. In material killed in vom Rath's fluid it appears with the greatest distinctness as a sharply defined median area composed of high columnar cells situated immediately in front of the peg-like tooth (Plate 25, fig. 10). In alcoholic material the appearance is not so striking, and yet there is very little difficulty in distinguishing the organ. However, with such material it is sometimes a task to determine its innervation. Nerves in the immediate vicinity are usually visible, but to trace these into the ganglia is frequently a perplexing operation. In vom Rath's material on the other hand the entire system is clearly differentiated (see section on nervous system).

The radula and its supports (Plate 25, fig. 2) are of comparatively large size but are typically arranged and require no especial description. Beyond the radula the gut becomes circular (Plate 25, fig. 3), the epithelium relatively high and a finely granular secretion fills the distal two thirds of the component cells. Among these are a very few more globular elements with a darkly staining more granular secretion. Beyond the pharynx the gut widens, the cells become lower and slightly glandular with the exception of a very few cells containing a yellow secretion. Beyond this point the relations of stomach, intestine, and liver are typical and require no detailed description.

The brain and anterior portion of the nervous system closely resemble what is found in *C. erudita*, and so require but little additional description. It appears that the labio-buccal connectives have an origin independent of the lateral and pedal, which as in *C. erudita* unite before entering the brain. The commissures of the pedal cords are relatively more slender than those of *C. erudita*, save the anterior one which is of exceptional thickness. In some cases nerves arise from the commissures and are distributed to the body wall.

The labio-buccal system is of unusual interest since it possesses what may

be considered to be a subradular system with ganglia and connectives with fibres passing into the above described organ in front of the radula. The labio-buccal connectives pass backward as usual and unite with the well-known ganglia imbedded in the pharyngeal musculature: and these bodies are in turn united by a cord in which two small ganglia are intercalated. A nerve which apparently has escaped observation arises from the posterior surface of each of the larger ganglia (Plate 13, fig. 3), and imbedded in the pharyngeal wall may be traced to the forward border of the stomach.

A short distance in front of the labio-buccal ganglia a clearly defined fibre arises from each of the connectives (Plate 13, fig. 3), and, imbedded in the muscle of the pharynx, courses downward and inward and joins a ganglionic mass that gives slight evidence of being paired (Plate 25, fig. 10). To the outside of the ganglion (or ganglia) a nerve arises from each of these connectives uniting with the labio-buccal connectives, and coursing dorsally attaches to the base of the subradular organ.

There is absolutely no doubt of the existence of this system, the grayish nerves showing with great distinctness against the yellowish muscle fibres in material killed in vom Rath's fluid. In material fixed in alcohol on the other hand it is sometimes difficult to trace. The ganglionic mass may closely resemble a salivary gland and the nerves from it counterfeit muscle fibres; nevertheless with an oil immersion lens I have been able to demonstrate its presence in all the species of the genus described in the present paper, and in a specimen of *C. nitidulum* kindly sent me by Professor Hubrecht. As is more fully noted on page 172 I believe that the ganglion and its connectives constitute a subradular system the homologue of the one I have described in some of the Neomeniidae.

Posteriorly the pedal and lateral ganglia unite in the customary fashion, and at the point of union give rise to two small nerves which become closely applied to the body wall, and after branching are lost to sight among the longitudinal somatic muscle fibres. From the suprarectal ganglionic mass (Plate 12, fig. 4), several branches arise some of which appear to have escaped observation, or at all events have not been traced to any considerable extent. Of these the larger pair originate from the ventral side of the ganglion and make their way ventrally to the sides of the rectum, where according to Wiren's figures and description they diminish very rapidly in diameter and form a delicate subrectal commissure. In the present species this is certainly not the case, nor is it true of *C. crudita*, for arriving at the rectum each follows it posteriorly to the anal opening, and then passes outward almost at a right angle and becomes imbedded

in the ventral gill retractors and in this position may be traced almost to the apex of the gill. Between its point of origin and its attachment to the rectum at least four small nerves arise and extend fan-like into the ventral gill retractors which they probably innervate. I have been unable to find any subrectal commissure.

From the dorsal side of the suprarectal commissure four nerves arise, of which the outermost pair extends dorsally through the superior gill retractors, and imbedded in the dorsal cloacal wall, which it probably innervates, may be followed for a very considerable distance. The inner pair pursues much the same route at first, but upon emerging from the dorsal retractors and while imbedded in the cloacal wall each nerve turns sharply upon itself, and bending slightly toward the mid line and somewhat ventrally it enters the dorsal gill retractor and in this position may be followed close to the tip of the gill. Each of the branchia thus has a double nerve supply as in the ctenidia of the Chitons for example.

The gonad, with the usual characteristics, opens into the pericardium by means of very short dorso-ventrally compressed tubes separated by the aorta. The pericardium is of unusual size, extending behind the heart nearly to the posterior end of the body. As may be seen Plate 36, fig. 2, it is interrupted by the dorsal gill retractors, but behind these muscles the cavity again becomes continuous across the mid line, extending down the sides of the cloacal cavity (Plate 25, fig. 5) and posteriorly forming a horn-like extension in the mid line. The heart is the usual tubular organ but posteriorly it unites with an atrium, which may be considered an auricle or an invagination of the ventral pericardial wall continuous posteriorly with the efferent branchial sinus.

The openings of the coelomoducts hold the usual position, at the sides of the suprarectal commissure, but the tubes with which they communicate are in the first part of their course very slender, ciliated, and somewhat convoluted. In this condition they extend ventrally and join the glandular portion (Plate 36, fig. 2). The cells of this secretory portion are of the usual type, almost cubical vacuolated elements containing a small concrement. The position of the external opening is shown (Plate 25, fig. 5).

Wiren ('92) has accurately described a patch of glandular epithelium, a modification of the cloacal wall, which on each side of the body surrounds the openings of the gonoducts and extends to a certain extent over the base of the gills. The cells composing it are high and consist of very slender supporting cells and glandular elements filled with an almost homogeneous substance, con-

taining in favorable preparations groups of small prismatic crystals. This description answers for the present species with the exception of the crystals which have not been found. Wiren compares this glandular area with the shell gland of the Neomeniidae, though claiming it acts as an excretory organ. Beyond certain histological resemblances there are no cogent reasons for accepting such a theory.

Chaetoderma erudita, sp. nov.

Ten specimens of this species were taken in Lynn Canal, Alaska (Sta. 4258) at a depth of 300–313 fathoms; and forty-one were dredged in Chatham Strait, Alaska (Sta. 4264) at a depth of 282–293 fathoms. In both cases the bottom consisted of very tenacious green mud. A number of individuals were kept in an aquarium aboard ship and lived apparently in a normal state, burrowing extensively and in some instances feeding on organic debris. Two males gave off considerable quantities of sperms during a period of over an hour. It escaped from the sides of the cloacal cavity, lateral to the gills and soon diffused into the surrounding water. Much care was taken in the preservation of these animals, and yet the shrinkage was considerable, in the case of some of the more active ones, amounting in six individuals to a decrease in the body length of one fourth. It thus becomes apparent that the length index or ratio of length to diameter is not to be depended on in the discrimination of species.

The entire animal is represented (Plate 4, fig. 9); the buccal plate (Plate 4, fig. 11), and the spicules (Plate 37, fig. 15). The hypodermis comprises three fairly distinct types of cells. Of these the most conspicuous, in alcohol killed material, is the basal cell of each spine whose nucleus is placed considerably above the level of the other types. In material killed in vom Rath's fluid the Reizenzellen of Wiren, well-defined globular cells, are very distinct and contain a highly vacuolated material which almost totally disappears in alcohol killed specimens. In some cases fibres, probably muscle, attach to these elements as in *C. attenuata*, but their relations are difficult to determine. The remaining cells are simple low columnar elements of the usual appearance.

The mouth, a relatively wide opening in the deeply cleft buccal plate, opens into a laterally compressed buccal tube that beneath the brain develops longitudinal folds and a more circular outline (Plate 29, fig. 4). As far as the forward end of the radular supports buccal glands in great abundance are attached to its walls. The subradular organ is not as sharply defined as in *C. attenuata*, yet is clearly distinguishable as a median ventral elevation composed of slender

columnar cells of greater height than those of the adjoining epithelium. In one specimen killed in vom Rath's fluid the protoplasm of the component cells is much vacuolated or in a very small number contains a granular secretion. Posterior to the radula, whose general appearance is sufficiently shown (Plate 29, fig. 8), the pharynx becomes dorso-ventrally compressed, then circular and opens into the stomach. This is a relatively spacious organ with thin unfolded walls that posteriorly become thicker and folded. The relation of intestine and liver are typical and require no description. In the proximal part of the liver, and throughout the major portion of the intestine, there are considerable quantities of organic remains, diatoms, sponge spicules, a few fragments of entomostracans, and several chambered Foraminifera whose protoplasm was only partially digested.

The nervous system of this species is exceptionally clearly defined in one specimen killed in vom Rath's fluid and for this reason has been more thoroughly studied than any other species of the genus described in the present paper with the exception of *C. attenuata*. The brain is very distinctly bilobed, a deep indentation occurring on its anterior surface. From its lateral and forward borders nerves pass into the precerebral ganglia which in turn send tremendous bundles of fibres to the buccal sensory plate. In some species the connectives to the pedal, lateral, and labio-buccal systems have distinct origins in the brain, but in the present case they are united for a considerable distance (Plate 13, fig. 3). Each of these compound connectives after leaving the brain and passing forward a short distance gives rise to the labio-buccal connective and considerably farther on the pedal and lateral connectives become differentiated. The pedal and lateral ganglia are in the usual positions and are united by frequent connectives and commissures. At the points of origin of these nerves there are no very clearly defined enlargements though anteriorly the pedal and lateral cords are of large size and gradually taper posteriorly, attaining their average size about the hinder border of the prothorax. As these ganglia diminish in size the connectives and commissures become reduced in calibre and are difficult to follow yet they may be traced here and there throughout the entire length of the animal.

As in *C. attenuata* a nerve arises from each labio-buccal connective about the level of the forward border of the radula and passing inward and downward joins a small subradular ganglionic mass. In this species the ganglion shows no indication of being paired. Each of these subradular connectives gives rise to a nerve distributed to the subradular organ and more laterally swells

somewhat though ganglion cells are lacking. From each of these enlargements a nerve is developed, and after branching in the pharyngeal musculature becomes lost to view. This subradular system does not appear with the diagrammatic clearness of the one in *C. attenuata*, but there is no especial difficulty in determining its relations which are essentially the same in the two species.

In the posterior regions of the body the nervous system very closely resembles that of *C. attenuata*.

The gonad, with the usual characteristics and relations, opens into the forward end of the pericardium by means of comparatively large tubes in sexually mature animals. In some animals, possibly owing to killing fluids, the pericardial cavity is greatly distended with spermatozoa which have made their way into the proximal half of the coelomoducts. These last named tubes communicate by wide openings with the pericardium and on the other hand extend forward as ciliated tubes for a short distance. Beyond this point their walls become glandular and are thrown into numerous convolutions which render it impossible, without much effort, to determine their exact relations. Posteriorly each duct becomes more simple, though of fairly large calibre, so that it contracts the cavity of the cloacal chamber; and on the ventral border of the fold thus developed the outlet canal is formed (Plate 29, fig. 5).

Chaetoderma montereyensis, sp. nov.

This species is evidently abundant in the deeper waters of Monterey Bay, California, as 155 were taken distributed through the following stations: nine from 4485, seven from 4508, fifty-nine from 4522, fifteen from 4523, thirty-one from 4524 and thirty-four from 4525. In every case the bottom was mud and the depth varied from 39 to 356 fathoms. Chloretone (aceto-chloroform) was used with good results as a narcotizing agent and 70 % alcohol served as a fixing agent. The length of a medium sized specimen[1] is 45 mm. with an average diameter of 2 mm. through the prothorax and 3 mm. through the preabdomen. The color in life and preserved material is yellowish white.

The hypodermis very closely resembles that of *C. attenuata*. The spines are represented in Plate 37, figs. 2, 3.

The mouth opens through a slit in the subelliptical buccal plate (Plate 4, fig. 17) and leads into a laterally compressed tube which becomes circular in

[1] Generally speaking the larger specimens come from the shallower depths. This is very marked in comparing those from Sta. 4525 with others from Sta. 4508. These size differences, however, do not appear to be correlated with any constant structural peculiarities.

outline slightly in front of the radula (Plate 27). Throughout its entire course to the hinder borders of the radula its walls, more than commonly muscular, afford lodgment for numerous salivary glands whose secretion stains darkly with haematoxylin. The radula, its supports and musculature are typically situated but are exceptionally heavy and powerful. The remaining divisions of the digestive tract are related as usual and are represented on Plate 27. Countless thousands of diatoms, together with nondescript organic and inorganic remains, fill the intestine and in some specimens, the stomach.

The pericardium is a comparatively spacious chamber, extending backward some distance over the cloacal cavity (Plate 27, fig. 9), and is perforated by the superior gill retractors; but otherwise neither it nor the tubular heart and the connecting sinuses are peculiar in any important particular.

The nervous system has been studied in considerable detail, and in all essential respects has been found to resemble that of *C. attenuata* for example.

The gonad, with the usual characters, opens into the pericardium by comparatively wide, dorso-ventrally compressed tubes. The inner openings of the coelomoducts are likewise of large size (Plate 27, fig. 8) and the adjacent ciliated section also though the latter is unusually short. This ciliated section unites with a division of the glandular part (shown on the left, Plate 27, figs. 2, 8). The outlet (Plate 27, fig. 9) occurs in the customary position and is surrounded by the glandular modification of the cloacal epithelium as in *C. attenuata* and a few other species.

Chaetoderma argentea, sp. nov.

One specimen (Plate 4, fig. 7) of this species was taken in southern Alaska in the green mud of Behm Canal (Sta. 4231) at a depth of 82–113 fathoms. It was in a moribund condition and with the exception of slight movements of the body and gills gave no signs of life. The measurements are, total length 24 mm. diameter of the prothorax 1.6 mm. while the greatest diameter of the preabdomen was 2.6 mm. The color in life and in a preserved state was a silvery white.

The cuticle is scant in amount and the hypodermis is comparatively low and is composed of small cells cubical or low columnar in form. Among these are the giant cells (Reisenzellen) from which the secretion has disappeared but they are attached to faintly staining fibres whose exact relations have not been determined. The spines are represented (Plate 37, fig. 6).

Although the animal when captured was alive it never relaxed sufficiently to allow the buccal sensory plate to become exposed. In sections this last named

organ appears to be typical though the glands that open along its margin are more than usually developed. The preradular section of the gut is of average diameter, fairly muscular and is provided with numerous glands uncommonly compact except on the dorsal side behind the brain. Violent contractions of the prothorax have apparently been responsible for the dislodgment of the epithelial lining of this part of the digestive tract; but there are indications that a subradular organ exists and the nerve supply is distinctly evident. The radula is constructed on the usual plan as may be seen (Plate 26, fig. 2). Beyond the radula the gut becomes narrow, circular in section and very soon unites with the capacious stomach whose relations to the intestine and liver are of the usual type. The stomach and especially the intestine contain a considerable amount of inorganic and organic material, diatoms being especially abundant.

The single specimen is a male with the gonad distended with sex products in all stages of development. Violent muscular contractions have forced a mass of sex cells, many of them immature, into the pericardium; and at various points along the coelomoducts fully developed sperms are present. The reno-pericardial openings, at the level of the posterior border of the suprarectal commissure, are relatively wide and lead into correspondingly spacious, highly ciliated tubes which pass almost directly ventrally to a point about opposite the mid lateral line where they unite with the glandular portion (Plate 36, fig. 1). This last named section extends as a slightly convoluted tube to a point about opposite the posterior border of the gonad where it bends sharply upon itself and ventral to the dorsal ciliated section opens into the cloacal chamber at the usual point.

The nervous system shows with distinctness and has been traced in considerable detail, but as the results show it to be essentially the same as in *C. attenuata* and *C. crudita* it demands no especial description. The subradular ganglion with the usual connections is clearly a single mass.

Gland cells in the gills are very definitely distributed, in cross sections being disposed along the transverse axis of the body (Plate 26, fig. 5).

Chaetoderma scabra, sp. nov.

One individual was dredged in Monterey Bay, California at a depth of 795–871 fath. It measures 12 mm. in length, 1 mm. through the metathorax and 2 mm. through the greatest diameter of the preabdomen. The expanded portion of the prothorax is light brownish yellow; more posteriorly the brown shade is more pronounced, becoming olive-green in the region of the liver which

shows through the translucent body wall. An orange-brown substance incrusts the spines about the cloacal opening. The spicules are represented (Plate 37, fig. 19).

The form of the buccal plate and the position of the mouth opening are shown (Plate 4, fig. 16). The adjacent section of the digestive tube rapidly assumes a circular form in section, and a few compact groups of gland cells become applied to the dorsal, and to a less extent the lateral walls. Immediately behind the brain these lobules become larger (Plate 30, fig. 3), but soon disappear more posteriorly. The radula was cut obliquely and it is therefore somewhat difficult to determine its exact relations. The tooth appears to be relatively slender, but its supports and musculature are typical. Behind the radula the pharynx again becomes circular and in this form joins the stomach (Plate 29, fig. 9). This last named organ is at first thin walled, but the epithelium soon grows higher, becomes folded and soon smooths out at the level of the posterior end of the prothorax (Plate 29, fig. 11). Again becoming thick walled and of small calibre it unites with the liver and intestine. From this point onward these last mentioned organs are of the usual type.

The pericardial cavity is of more than average size (Plate 29, fig. 10) and the heart is highly muscular; otherwise neither these organs nor the connecting sinuses are unusual.

The specimen is sexually mature and multitudes of sperms have made their way from the gonad through wide tubes into the pericardium and the proximal portion of the coelomoducts. The openings of these latter organs into the pericardial cavity are comparatively large and the ducts themselves are relatively simple. As in some other small species the glandular portion is a simple canal extending as far forward as the posterior end of the gonad where it bends abruptly and making its way posteriorly opens by an inconspicuous pore into the cloacal chamber.

The nervous system is distinct and sharply defined and has been carefully examined, but it does not differ in any important respect from that of *C. erudita* for example.

Chaetoderma californica, sp. nov.

One specimen was collected in the neighborhood of San Diego, California, (Sta. 4381) at a depth of 618–667 fathoms. It measures 24 mm. in length by 1.6 mm., the average thickness of the metathorax, and 2 mm. the average diameter of the preabdomen. The general appearance of the animal and the relative length of the various divisions of the body are shown (Plate 4, fig. 6). The color

of the protrusible portion of the prothorax is yellowish brown, while the remainder of the body is yellowish green. A rusty red substance, possibly excreta, incrusts the spines in the cloacal region.

The cuticle is of moderate thickness and rests upon a hypodermal layer whose nuclei, placed at various levels in the region of the prothorax, have at first sight the appearance of being more than one cell thick. The most common type of cell is relatively slender and contains an oval granular nucleus. Among these are other elements, probably spicule matrix cells, each of which contains a spherical nucleus larger in size than those of the foregoing class of cells and placed in the neighborhood of the base of a spine above the general level of the hypodermis. As in *C. attenuata* spaces exist at frequent intervals in the hypodermis and from the vicinity of each fibres pass into the underlying muscular layer. As noted on page 55 there are reasons for the belief that these are gland cells, of unknown function, whose secretion is dissolved through the agency of alcohol when used as a fixing agent. The shape of the spines is shown (Plate 37, fig. 14).

The alimentary canal opens through the dorsal half of the buccal plate; its first section (Plate 27) is a narrow canal that rapidly widens in the neighborhood of the brain. To its lining epithelium the usual muscles attach and afford lodgment for numerous buccal glands. These last named organs extend from the mouth to the level of the brain and are similar to those of *C. nitidulum* save that the cells are less compact and of larger size. In the neighborhood of the radula the walls of the pharynx become more folded than in *C. nitidulum* and are unique in possessing a pouch (Plate 31, fig. 8) of considerable extent, into which the glands of the dorsal side open. Behind the radula the canal gradually narrows, its folds become smoothed out whereupon it unites with the stomach.

The salivary glands consist of several globular cells surrounding a small lumen that in some instances is in direct communication with the digestive tract. However each cell communicates with a small ductule which gives evidence, not of passing the secretion into the lumen of the gland, but directly into the digestive tract through intercellular channels of the lining epithelium.

The radula presents no especially noteworthy features. Its conical tooth is slightly more slender than is usual (Plate 31, fig. 1), but the cuticular wing-like supports and musculature are entirely typical.

As usual the pharynx opens by a comparatively narrow pore (Plate 31, fig. 2) into the stomach whose relations to the liver and intestine are normal. Large quantities of organic remains occur in the gut, Radiolaria, diatoms, and sponge

spicules being distinguishable. Associated with these are numerous rounded cells (Plate 35, fig. 11) that occur also in the digestive gland. In most cases these are free but occasionally one may be seen that is encysted in the cells of the organs mentioned. Rarely they are associated in pairs as though in the process of conjugation.

The gonad holds the usual position and like the sperms, in all stages of development, presents no noteworthy characters. Posteriorly the halves of the organ diverge, become rather indistinct though their route may be traced with certainty, owing to the presence of spermatozoa, passing lateral to the heart or the expanded base of the aorta and opening into the pericardium. This last named space lacks the almost diagrammatic outline as in *C. nitidulum* and is much more limited in extent, but its relations to the gonoducts are very similar.

Chaetoderma nanula, sp. nov.

One specimen of this species was dredged off the coast of southern California (Sta. 4369) at a depth of 260–284 faths. It is 9 mm. in length by 0.9 and 1.2 the average diameter of the metathorax and preabdomen respectively (Plate 4, fig. 1). The color of the globular, protrusible portion of the prothorax is light brownish yellow (though this may have been produced by tannin from the cork), while the metathorax and preabdomen are considerably darker, the latter region becoming olive-green. A dark brownish substance incrusts the spines about the cloacal opening. The hypodermal layer is comparatively thin, the cells small and somewhat indistinct, yet are typical so far as may be determined. The spines are represented (Plate 37, fig. 18).

The mouth opening represented (Plate 4, fig. 12), leads into a relatively spacious tube lined with slender columnar cells except along the dorsal side where they are almost cubical. A median fold, located immediately in front of the radula, probably represents a subradular organ since it is typically innervated. Salivary glands are almost wholly lacking, a small group attached to the pharyngeal wall adjacent to the radula being all that is visible in the present specimen. The radula is small but typical. Beyond it the tube narrows considerably, the lining becomes folded and in this form it unites with the stomach. At the outset this last named organ is plain walled but near its union with the liver becomes considerably sacculated. The intestine is distended with fragments of Radiolaria, sponge spicules, and organic debris. Parasitic Protozoa, resembling those from *Chaetoderma californica*, are abundant and are imbedded in the epithelial lining of the stomach, intestine, and liver throughout their entire extent.

The animal is a female, not perfectly mature, and the ducts leading into the pericardium are accordingly small. The openings into the coelomoducts are likewise minute, and the ciliated tube with which each connects is relatively long and slender. The glandular division with which it unites is a comparatively simple tube, at first directed forward until it reaches the level of the front end of the heart whereupon it bends abruptly and makes its way to the opening into the cloacal chamber (Plate 28, fig. 10).

The nervous system is in an excellent state of preservation and is clearly defined, but a careful study has failed to disclose any noteworthy feature. It may be mentioned that a subradular system exists similar in all respects to that of *C. attenuata*.

Chaetoderma japonica, sp. nov.

One specimen (Plate 3, fig. 7) was dredged off Honshu Island, Japan (Oi Gawa, Sta. 3721) at a depth of 207–250 fathoms. The body is comparatively slender, measuring 17 mm. in length by 1.3 mm. through the metathorax and 1.5 mm. through the preabdomen. The color is almost white with a slight tinge of yellow. A slight incrustation, brick-red in color covers the spines in the cloacal region. The spines are of the usual type.

The mouth opens through a distinct pore in the buccal plate (Plate 3, fig. 8) which, like the neighboring section of the digestive tube, is abundantly supplied with glands, small celled and more than commonly compact. These continue, for a considerable distance behind the radula, apparently unchanged in character though in many cases closely applied against the bases of the buccal and pharyngeal epithelium. This first named organ with its supports and musculature is typical, as may be seen in Plates 30, 31. As the major portion of the body was not sectioned the union of liver and stomach has not been seen; otherwise these organs conform to the usual plan. The prerectal portion of the intestine is lined with an exceptionally high epithelium so that the lumen is very small where it is not distended with pellets of faecal matter consisting principally of diatoms and sponge spicules.

The nervous system is not especially favorable for study and accordingly only its more general features have been examined. In this respect it is typical.

The specimen is a female and the fully formed ova present the customary appearance and are developed in a gland holding the usual position. The ducts leading into the pericardium, are large and as in the case of the last named space, and the gonoducts, are filled with eggs mostly disintegrated, due perhaps to violent movements of the somatic musculature. The gonoducts open by rela-

tively large pores into the pericardium and as moderately spacious tubes without any marked convolutions, extend to their openings into the cloaca (Plate **30**, fig. 7). Surrounding these pores the cloacal epithelium is modified to form the glandular area similar to that of *C. attenuata*.

Chaetoderma robusta, sp. nov.

Four specimens of this species were taken south of the Alaskan peninsula (Sta. 3210) in green mud at a depth of 483 fathoms. The largest specimen (Plate **4**, fig. 5) is 60 mm. long with an average diameter through the metathorax and preabdomen of 3.5 and 4.7 mm. respectively. The smallest is 35 mm. long with an average metathorax diameter of 2 mm. and 3 through the preabdomen. Where the spines have not been dislodged the general color of the body is slaty gray shading to buff at the anterior end of the body. A yellowish brown substance incrusts the spines about the cloaca.

The hypodermis consists of numerous small cells rather closely crowded so that the cells lack distinctness. However giant cells are visible and faint fibres, connective tissue or muscle, springing from the underlying body wall appear to attach to them. Spicule-matrix cells in all stages of development are visible, and in each case the spines are attached to only one cell so far as it is possible to judge. The remaining elements are comparatively slender, compact and lack any noteworthy features. The spines are represented in Plate **37**, fig. 4.

The buccal plate is shield-shaped in outline (Plate **4**, fig. 19), and is pierced by the mouth opening. The buccal and pharyngeal cavities are slender, and the walls of more than average thickness (Plate **30**). The lining cells are accordingly very slender, ciliated and are thrown into a few prominent folds. The ductules of a very large number of salivary glands make their way between the cells and in some cases are in the act of pouring their secretion into the canal. A subradular system is present, and as usual two nerves are distributed to a median fold of pharyngeal epithelium that probably functions as a subradular organ. However with the exception of affording scarcely any outlet for the salivary glands its cells are not clearly distinguishable from the general epithelium. The radula consists of the usual conical tooth, rather heavier than usual, but with supports and musculature of the customary type. Beyond the radula the tract becomes circular in cross section before uniting with the stomach whose relations to the liver and intestine are typical.

The circulatory system presents no noteworthy features beyond the fact that the heart is suspended by a fold of the pericardial wall reinforced by a few

connective-tissue fibres, and is surrounded by a pericardial cavity that posteriorly extends as a slit-like space between the cloacal and body walls far along toward the posterior end of the body.

In its general features the nervous system closely resembles that of *C. erudita* and *C. attenuata*. The labio-buccal system has been worked out in detail, but it is no exception to the statement just made.

The gonad is of large size and is distended with spermatozoa that have made their way through wide canals into the pericardium. As usual the pericardial openings are situated close to the suprarectal commissure, and lead into clearly defined ciliated ducts which very soon unite with the glandular portion. In this species the glandular portion is at first relatively slender, and but little convoluted yet it soon enlarges greatly, becomes much folded and extends as may be seen in Plate 30, figs. 5, 7, from the posterior limit of the gonad to its opening into the cloacal cavity.

Limifossor talpoideus Heath.

Zool. Anz., 1904, 5, p. 28. Zool. Jahrb. Abth. Anat. Ontog., 1905, 5, p. 21.

Several specimens of this species were taken in Alaska in the Lynn Canal (Sta. 4258) and in Chatham Strait (Sta. 4264) at depths ranging from 282–313 fathoms. The general appearance of these animals is shown (Plate 10, fig. 1). The length ranges from 6–12 mm. and the diameter from 1–2 mm., the ratio 1:6 being constant.

The mouth, almost terminal in position, is bounded by the sensory plates (Mundschild) and more dorsally by the type of spine covering the prothorax generally. The plates in life undergo rapid changes in form, but histologically and in their innervation they resemble their homologue in Chaetoderma. The deep semicircular groove (halbmondförmige Grube) situated beneath the mouth and sensory plates, is lined throughout with the spiculose integument of the body. The spines are triangular or leaf-like and range in length from 0.02 mm. in the region of the mouth to those about the cloacal chamber 0.38 mm. long.

The hypodermis is relatively very thin, the boundaries of the cells indistinct and similar in general to that of other species of Chaetoderma. The somatic musculature likewise is very similar in the two genera.

The mouth leads into a comparatively narrow canal with longitudinal folds covered with a well-defined cuticle. In the region of the radula the canal enlarges, develops a subradular pocket (Plate 10, fig. 4) and dorsally continues as a circular tube to its junction with the stomach. Attached to a dorsal diverticulum numerous cells pour their secretion into the pharynx. A clearly defined subradu-

lar organ does not exist and yet the fact that in the mid line the cells are more than usually high and slender and are in close proximity to nerves from the labio-buccal ganglia indicates that the area exercises a sensory function. The radula and its supports and attendant musculature are enormously developed and indicate active predatory habits, but in every case the alimentary canal contains little besides a few diatoms, sponge spicules, and a small quantity of inorganic detritus. The radula with twenty-eight transverse rows is of the distichous type (Plate 34, figs. 3, 6), the long claw-like teeth being united while in the radula sheath by a clearly defined basement membrane. When freely exposed this membrane splits along the mid line and the teeth become located on each side of a deep cleft in the forward end of the radular supports (Plate 10, fig. 10). Odontoblasts, in typical fashion, form the teeth which are subsequently enveloped by numerous enamel cells.

The radular supports comprise two great masses of muscle and connective tissue which together form an ovoid mass grooved dorsally to hold the radula tube. To these numerous muscles attach that are in part responsible for the movements of the teeth. A detailed description of these and other muscle bands has been given in another place (Heath '05) and an attempt has been made to determine their functions.

The stomach is sharply differentiated from the remainder of the digestive tract (Plate 10, fig. 4) and occupies practically all of the space between the end of the radular supports and the forward border of the gonad and digestive gland. Its epithelial lining is produced into a number of heavy folds that gradually blend with those of the oesophagus. In most cases the intestine leaves the posterior end of the stomach in the mid line, and immediately ventral to this union the liver opens by a single pore. This last named organ is relatively voluminous, filling much of the space beneath the gonad between the stomach and forward cloacal wall where it ends blindly. The intestine, of practically the same calibre throughout, makes its way by a fairly direct route to the front end of the pericardium. Here it bends abruptly downward and passing under the cloacal wall opens to the exterior in the mid line.

A clearly defined connective-tissue septum bounds the head cavity posteriorly as in the Chitons. It passes immediately behind the radular supports and is penetrated by the alimentary canal, dorsal aorta, and pedal sinus.

The pericardial cavity is of trihedral form and encloses a tubular and more than usually muscular heart without any distinct subdivisions. The aorta passes out from its forward border, and as a distinct tube with definite walls

makes its way between the halves of the gonad to an opening in the septum bounding the head cavity. This latter space communicates with a well-defined pedal sinus, which perforates the septum and pursues its course posteriorly, communicating here and there with the general visceral cavity, to the neighborhood of the cloacal cavity. Here both sinuses unite on their way to the gills from which the blood passes above the dorsal gill retractor to enter the heart.

The brain, clearly bilobed, develops fibres which unite with five pairs of precerebral ganglia that in turn give rise to nerves passing to the sensory plate. The lateral, pedal, and labio-buccal connectives unite before entering the brain. The last named are first to be differentiated and holding the usual position at the sides of the pharynx, they unite with the ganglia lateral to the dorsal salivary glands. These nerve masses are united by the usual commissure and by another passing dorsal to the pharynx in the neighborhood of the salivary glands. What appears to be a complete one passes ventrally into the neighborhood of the subradular organ. A nerve from each ganglion passes backward and probably innervates a portion of the digestive tract. The lateral and pedal ganglia, with the usual relations, extend to the region of the cloaca where they unite to form on each side a well-defined enlargement connected by a suprarectal commissure. From each swelling several nerves arise that are distributed to the cloacal and body walls; while from the commissure branches are developed, dorsally and ventrally, that innervate the ctenidia.

The gonad extends from the stomach to the pericardial cavity into which it opens by relatively long and slender ducts. The coelomoducts have the form of simple tubes extending from the pericardium to separate exits in the cloacal chamber. Their inner openings are situated in the infero-lateral angles of the pericardial cavity and are guarded by high pyriform cells devoid of cilia. On the other hand the succeeding portion of the canal, of very small calibre, is composed of cubical elements covered with a heavy ciliated coat. This division makes its way forward to the outside of the dorsal gill retractor and unites abruptly with the glandular portion, which although a single tube is so convoluted that it becomes a relatively voluminous structure. Its walls are composed of more or less cubical cells of which the cytoplasm is scant in amount owing to the presence of one or two great vacuoles. The general structure bears a fairly close resemblance to certain kidney tissue yet there is no positive proof that it possesses an excretory function. The outer openings are on each side of the anus a short distance anterior to it, and though very minute in preserved material they are nevertheless clearly defined.

Limifossor fratula, sp. nov.

This species is represented by two individuals taken off the coast of southern California (Sta. 4369) at a depth of 260–284 fathoms. In general it so closely resembles the foregoing species that a very brief description will suffice. The body, slaty gray in color with a slight yellowish cast, is shorter and thicker than in *L. talpoideus*, and owing to a heavier body wall is much firmer. The spines of the two species are very similar in form, but in the present species they are of considerably larger size. Spicules from the middle of the body are 0.5 mm. in length while in *L. talpoideus* the largest of the body do not exceed 0.38 mm. The hypodermis is also proportionately thick and what are probably matrix cells are frequent and sharply differentiated from the other elements of the hypodermis, and hence different from *L. talpoideus* in this respect.

The digestive tract in the two species is, neglecting minor differences, built upon the same plan. Heavy as is the radula and its supports in *L. talpoideus* it is even heavier in the present case, and the teeth are of larger size, making it so difficult to section them that at present there are no clear indications of their exact shape though it appears certain that the smaller cusp of each tooth is larger than in the preceding species. The muscles that operate the radula are typical but are unusually heavy.

The nervous, circulatory, and reproductive systems are very similar in the two species.

This species is readily distinguished from the foregoing by the size of the spines, the structure of the hypodermis, and the heavier musculature and consequent firmness of the body.

Pachymenia abyssorum, sp. nov.

One specimen of this species was dredged off the southern coast of California (Sta. 4397) in 2196–2228 fathoms, the greatest depth recorded for any Solenogastre. In bringing the animal to the surface the consequent decrease in pressure upon the body resulted in the active release of gases from the blood, causing the displacement of the cuticle to a considerable extent, the shrinkage of the hypodermal cells and the partial destruction of the foot at various points; otherwise the tissues are in a good state of preservation. The body is thick set, externally resembling *Alexandromenia valida*, and measures 27 mm. in length by 4.5 mm. average thickness. The color is a light yellowish white. As is indicated (Plate 39, fig. 4), the foot is exposed for a considerable distance, and is unusually broad and doubtless in life is capable of forming a relatively large

surface possibly enabling the animal to crawl about on the bottom ooze. As in the case of Alexandromenia this individual is unattached and may be accordingly a roving form.

The cuticle is approximately three times the thickness of the hypodermis, but is scant in amount owing to the vast numbers of needle-like spicules, of varying sizes, imbedded in it. As noted above the hypodermal layer is not in a good state of preservation, but it may readily be discovered that the cells are unusually slender, and laterally and ventrally form papillae in the head region. There are low elevations at other points over the body but it is not certain that they are definite papillae.

The external opening of the anterior pedal gland is a cavity of large size whose walls are provided with folds of unusual height. On the posterior wall these are approximately seven in number, the outermost on each side being very large. Behind the cavity the five included folds disappear while the large lateral ones unite in the formation of a foot with a creeping surface of greater width than in any other known species of Solenogastre. In the posterior end of the body the foot decreases in size and becomes continuous with small folds of the cloacal wall.

The anterior pedal gland is a voluminous organ lying at the sides of the body opposite the external outlet. The cells composing it are exceptionally small but otherwise present no noteworthy characters. Behind it shades into the posterior pedal gland without any appreciable change in the character of the cells. Throughout the entire extent of the foot the gland is unusually large and the ductules appear to open over the entire creeping surface.

The external atrial opening is subterminal and large, and leads into the customary cavity provided with ridges and cirri typically situated. As may be seen in Plate 39, fig. 1, the external ridge is continuous across the mid line in front of the external opening of the atrium and though relatively small at this point it rapidly increases in height, finally becoming of such a size that it may be seen in external view. The inner ridge is likewise small anteriorly but behind becomes as extensive as the external fold. Behind these two folds are continuous with each other and are connected with several long plaits in the hypodermis which extend to the external opening of the pedal gland. The cirri are simple unbranched processes, slightly pigmented and contain a muscle or nerve fibre extending, in some cases at least, throughout their entire extent.

The atrium communicates dorsally with the succeeding section of the digestive tract whose general relations may be determined from an examination

of Plate 39, figs. 1, 6. The walls of this division are provided with numerous muscle bundles of irregular distribution between which are multitudes of glands staining actively when treated with Delafield's haematoxylin. The cells composing these glands are without distinct cell boundaries, are made up of vacuolated protoplasm containing droplets of various sizes and are grouped into lobules of various bulk. In many places they extend into the folds of the epithelial lining of the pharynx and give evidence of opening through intercellular channels.

Some distance toward the dorsal side of the animal a fold of large size appears in the wall of the digestive tract which narrows the pharyngeal cavity to a relatively small tube. At this point the epithelial lining becomes thicker, a character which it retains to the stomach-intestine, and the walls become surrounded by a heavy sheath of circular muscles to which vast number of gland cells attach. These gland cells are grouped into slender lobules, and owing to the fact that they are much vacuolated their tint is fainter than in the case of those of the preceding division of the tract. The nuclei also are of larger size and more distinct, but the secretion presents the same general appearance. A slender duct on each side of the pharynx (Plate 40, fig. 6) extends from the region of the ventral labio-buccal commissure (Plate 39, fig. 8), to its outlet (Plate 39, fig. 6). Posteriorly each ends blindly and anteriorly is provided, as in the case of Alexandromenia, with a papilla which is doubtless capable of being protruded into the pharyngeal cavity. Throughout its entire extent the ductules from these glands attach to the canal, but behind it they connect with intercellular channels and so pour their secretion directly into the pharyngeal cavity. The glands with this last named outlet present the same appearance as those communicating with the ducts except in the neighborhood of the stomach-intestine where they become more compact.

No trace of a radula or radula sac exists.

The pharynx or oesophagus projects for a great distance into the stomach-intestine which is provided with several longitudinal ridges instead of the customary sacculations. The middle portion of the body was not sectioned but as these ridges are present in the posterior end of the animal it is probable that they extend throughout the entire length of the gut. Many of these folds contain blood sinuses which often produce a marked distention. The lining epithelium is composed of more than usually slender cells many of which contain more or less spherical, granular masses. Posteriorly the intestine narrows, passes between the coelomoducts and opens into the cloacal chamber. No

traces of food were found in the tract and accordingly we are without any knowledge of the animal's feeding habits.

The walls of the cloacal chamber are provided with a number of slender outpouchings and to these are attached multitudes of gland cells grouped into lobules of different sizes. Each cell is pyriform and contains a somewhat granular slightly vacuolated secretion that makes its way by a delicate ductule through an intercellular opening into a diverticulum of the cloacal wall. The general arrangement of these structures is shown in Plate 39, fig. 2.

The pericardial cavity is comparatively spacious and the contained heart, consisting of two divisions, is moderately muscular. The aorta in the present specimen is of small size but in its relations to the gonad and the anterior end of the body it is typical. Owing probably to the size of the foot the ventral sinus is large and connects in the usual fashion with the head sinuses and here and there throughout the body with the visceral sinus. In the posterior part of the body it divides, passes dorsally on each side of the intestine and after passing posteriorly for a short distance breaks up into a small number of lacunae which connect with the gills. From these organs the blood passes through rather ill-defined channels in the somatic musculature to the posterior end of the heart.

Five or six pairs of relatively large folds appear in the cloacal wall running more or less parallel to the outer opening near which they are situated (Plate 39, fig. 2). Here and there these develop numerous minor wrinkles (Plate 40, fig. 7) which pass from one main fold to another or extend some distance over the cloacal wall. As usual they all contain blood sinuses but otherwise are not especially modified.

The brain, imbedded in the numerous glands attached to the forward wall of the pharynx, is an unusually elongated structure and without distinct signs of being bilobed. From its anterior face the usual nerves, heavy in appearance, are distributed to the body wall and the ganglionic masses about the bases of the cirri. The lateral, pedal, and labio-buccal connectives arise from the extreme lateral boundaries of the brain and follow the usual course. A very slight enlargement marks the point of union of the lateral ganglion with the corresponding connective, while one of twice the diameter occurs in the case of the pedal cords. The last named structures are united at fairly definite intervals by clearly defined commissures and about the same number of connectives attach to the lateral ganglia. A nerve from the anterior pedal enlargement passes to the wall of the outlet of the anterior pedal gland, and two branches originate from a corresponding point on the lateral ganglia and applied to the

somatic musculature extend far forward into the anterior end of the body. The labio-buccal connectives, imbedded in the pharyngeal glands, pass backward about half the length of the pharynx where they join the ventrally placed ganglia (Plate 39, fig. 8). These masses are in turn united by a strong commissure provided in its mid section with several ganglion cells from which a nerve arises and extends backward for a considerable distance attached to the pharyngeal glands. What appears to be a dorsal commissure springs from the upper side of the ganglia, passes dorsally and may be traced here and there amid the glands over the dorsal surface of the pharynx. It has not been followed throughout its entire extent yet I have but little doubt that it is a definite commissure. From the posterior borders of each labio-buccal ganglion a nerve arises and imbedded also in the glands of the pharynx extends for a considerable distance posteriorly before it becomes lost to view. Finally it may be said that the arrangement of the brain and anterior portion of the nervous system is more regular than in the case of Alexandromenia for example, but otherwise there is no fundamental difference.

In the posterior end of the body the pedal ganglia continue to be united by commissures of large size and practically the same number of connectives unite them with the lateral ganglia placed high up on the sides of the body. In front of the anterior cloacal wall the pedal cords bend dorsally and provided throughout with ganglion cells attach to the lateral nerve masses at the sides of the pericardial cavity (Plate 40, fig. 4). From the posterior end of the lateral and pedal ganglia nerves arise and extend backward along the body wall and in some places pass into the cloacal folds.

A well-defined dorsal sense organ is present whose location is represented (Plate 39, fig. 2). Owing to the fact that it is of small size, that the cells like those of the hypodermis are not well preserved and because of the oblique direction of the sections its structure has not been accurately determined yet so far as the examination has gone it appears to conform to the usual type.

The ovo-testis occupies the usual position on the dorsal side of the animal and extends forward to the posterior end of the pharynx. The ova are unusually large and are surrounded by a chorion, but with these exceptions neither they nor the spermatozoa present any especially noteworthy features. The ducts leading from the gonad into the pericardium are of comparatively large calibre.

In several respects the coelomoducts are remarkable structures and unlike those of any other known Solenogastre. In the vicinity of their inner openings

the pericardial wall becomes thickened and numerous small folds appear which converge and in some cases at least become continuous with the adjacent section of the duct. A short distance beyond the pericardial cavity and as far distally as the seminal receptacle each duct affords attachment for a vast number of glands of unknown function. These are slender diverticula (Plate 40, fig. 2), composed of very small cells with indistinct boundaries filled with a finely granular faintly staining secretion. In the present specimen large quantities of spermatozoa are present in the coelomoducts and frequently these have made their way into some of the diverticula where they form masses without definite arrangement. Whether this is a normal occurrence or a *post mortem* effect cannot be definitely decided with the material in hand. Beyond these glands the dorsal section of the coelomoduct becomes thin walled, without folds and soon joins the ventral division which as Plate 39, fig. 2, indicates is of large size, thin walled, with few folds and is crowded with sperms. Immediately ventral to the union of the dorsal and ventral limb of each duct there is a small globular outpouching to whose internal wall large numbers of spermatozoa are attached so that in position and function it is to be considered as a seminal receptacle. Sperms with the same mode of attachment are found in considerable numbers adjacent to the seminal receptacles and rarely at much greater distances, even as far as the undivided section or shell gland. The cavity of this last named organ is not much larger than that of the dorsal section and its epithelial lining is relatively thin but a multitude of glands, attached throughout its entire extent, give it a heavy appearance. These glands are composed of compact, pear-shaped cells arranged in lobules that open by intercellular channels in the epithelial lining of the shell gland. As may be seen in Plate 39, fig. 2, the shell gland pushes inward the anterior wall of the cloacal chamber so that its outlet is far within this last named cavity.

Drepanomenia vampyrella, sp. nov.

This species is represented by a single specimen dredged off the southern coast of Oahu Island (Sta. 3907) at a depth of 304–315 fath., where the temperature was 43.7 F. It was coiled tightly about a solitary polyp of Epizoanthus, and further examination showed that the proboscis of the mollusc was protruded through the body wall of the coelenterate, whose reproductive and other tissues had been drawn into the alimentary canal of its captor. There is therefore no doubt that this species is carnivorous and that its association with the actinian is not an accidental one or a case of commensalism.

The body (Plate 2, fig. 2) measured 9 mm. in length, was slightly compressed laterally, particularly its anterior half, and in form was somewhat spindle shaped, being largest about the middle section of the body and gradually tapering off toward each end, especially posteriorly where the body becomes quite slender before terminating in a truncated extremity. A well-defined keel extends along the entire animal in the mid dorsal line. The color was faint yellowish white.

The cuticle surrounding the body is of medium thickness, measuring 0.35 mm. in the keel and 0.28 mm. elsewhere in the dorsal region, but gradually decreasing to half this amount on the ventral surface. It includes a single layer of radially directed spicules (Plate 32, fig. 6), ranging in size from those in the first stages of formation to others of the keel 0.129 mm. long. All are of the same general form represented in Plate 37, fig. 7. It is to be noted that many of the spicules are not in contact with the hypodermis, even the matrix cells having disappeared, but are situated far out toward the surface of the body. Beneath each developing spine are several cells apparently instrumental in its formation.

The cells of the hypodermis are very small and indistinct and accordingly have been examined only superficially. The prevailing cells are slender with subcentral nuclei, and are developed into numerous small elevations, some of which connect by strands with the overlying papillae (Plate 32, fig. 6). These last named organs contain upwards of eight cells in the enlarged portion; none appear to exist in the exceedingly slender stalk.

As in other species of the family the ventral furrow commences close to the hinder border of the lip, and extending the entire length of the animal becomes continuous with the cloacal opening. Anteriorly it contains a relatively deep excavation into which the anterior pedal gland opens by the usual numerous intercellular ducts. This last named gland occupies practically all of the visceral cavity between the region of the brain and the anterior end of the gonad. The cells composing it are generally pyriform, with an average diameter of .021 mm. and are filled, save for the small compact nuclei, with a finely granular substance that stains intensely with logwood dyes. In some cases this secretion appears to be undergoing solution, and presents a vacuolated appearance, a character that is very pronounced among the cells of the posterior pedal gland. These latter elements are related also to the foregoing in general form, size, and appearance, and extending to the cloaca and opening on each side of the foot, are thus seen to hold the usual position.

At the hinder border of the crypt into which the anterior pedal gland opens,

the foot arises as a single, small prominence and rapidly assumes its fully developed condition. Posteriorly it gradually decreases in size, disappearing, so far as may be judged from longitudinal sections, at a point immediately in front of the gonoduct openings.

The general relations of the anterior section of the digestive tract are fully represented in Plate 7, fig. 4. As will be seen the atrial opening is subterminal in position and of medium size. The relations of the succeeding parts, while much the same as in Proneomenia, for example, are somewhat obscured by the protrusion of the pharynx. An outer ridge, composed of the usual type of columnar cell though apparently lacking cilia (Mundleist), is present. The inner ridge, probably related as in other species, has in the present specimen been carried out on the tip of the pharynx, an interesting fact as it indicates that these cells may be sensory, and of service in determining the character of the animal's food or surroundings. Between these two prominences the usual cirrose area is present, the cirri being of relatively large size and unbranched. It has been suggested that the cirri, secreting a viscous material, may serve in the capture and retention of food. Here, however, is an animal killed in the act of feeding with its proboscis penetrating its host. The material drawn into the pharynx does not come into contact with the cirri, which in this case must certainly have some other function, though it is difficult to say what this may be.

In its present extended condition the pharynx is relatively slender, almost wholly devoid of longitudinal folds and is relatively muscular. Heavy retractor muscles attach to the buccal wall and serve to withdraw the pharynx, that appears to lack special retractors of its own. In some species of Neomenia the ventral salivary glands are described as being more or less coiled; in the present species this would probably be the case, but with the protrusion of the pharynx their openings into the canal have been carried forward until they are very close to the end of the proboscis. Each gland is unbranched, composed of excessively spongy cells and is possessed of a relatively large lumen, and a length of fully one fourth that of the body. In view of the fact that Drepanomenia has no radula it appears probable that the salivary secretion exercises a solvent action on the tissues of its victim, and the liquified material is then sucked in. The digestive tract in the present case is well filled with a finely granular substance in which one may recognize here and there the remains of cells, chiefly reproductive, belonging to its host.

As may be seen (Plate 7, fig. 4), the stomach-intestine extends forward a considerable distance in front of its union with the pharynx, thus forming an

extensive anterior cœcum. On this sack a number of short outgrowths are developed chiefly on the dorsal side. A short distance behind the front end of the gonad gut pouches appear arranged with great regularity, and from this point on digestive cells attain their fully developed condition. In the region of the pericardium the sacculations vanish, the canal narrows rapidly and the liver cells are replaced by low columnar cells thrown up into longitudinal ridges extending to the opening into the cloacal chamber.

In this specimen the pericardial cavity is relatively large (Plate 6, fig. 3), and the heart it contains is considerably distended with blood, rendering it possible to some extent to determine the course of the circulation. The blood returning from the gills, and another smaller portion that appears to come directly from the hinder portions of the body, pours into a well-defined auricle situated at the hinder end of the pericardial cavity beneath the ventricle. Its walls are only slightly less muscular than those of the ventricle, and owing possibly to muscular contractions, are developed into several pouches that do not have the appearance of blood glands. From the auricle the blood passes into the ventricle through a comparatively large opening guarded by a well-developed muscular flap probably functioning as a valve.

From the front end of the ventricle a clearly defined vessel arises, and passing forward unites with the dorsal aorta. This latter vessel holds its usual position between the body wall and gonad, but it extends backward over the dorsal side of the pericardium as far as the posterior end of the ventricle. Anteriorly the relations of the vessels in the gonad and of the aorta to the head cavity are essentially as they are in *P. hawaiiensis*. This appears to be the case also with the sinuses in other parts of the body, though using longitudinal sections through the somewhat twisted body, it is not possible without much labor, to determine their connections accurately.

With the protrusion of the pharynx the brain has been carried some distance ventrally, but under ordinary circumstances its position and the relations of the nerves which it develops are probably not unusual. As Plate 7, fig. 4, shows three pairs of nerves pass to the atrial wall as in other of the Neomeniina, and are probably destined, here as there, to supply the cirri, anterior musculature, and hypodermal sense organs. So far as may be judged from sections, the labio-buccal connectives originate some distance from the pedal and pallial, and may be clearly seen to pass down to ganglia situated on the sides of the pharynx where it unites with the buccal wall. From the hinder border of each ganglion a fibre originates that may be the inferior or ventral commissure, but

owing to innumerable muscles it was not possible to determine this conclusively. Neither was it possible on this account to determine if any subradular system exists.

The relations of the pedal and lateral ganglia call for few special remarks. In some places it was possible to demonstrate pedal commissures, and to trace connectives between the pedal and lateral cords, especially in the hinder regions of the animal where the cords are closer together. The most posterior connective is especially heavy (Plate 11, fig. 1), and develops two or three fibres whose branches may be traced to the musculature of the body wall. On the inside a very few exceedingly delicate nerves pass to the terminal section of the coelomoducts. From the posterior swollen section of the lateral cords (*ganglion superior posticus*) several nerves arise chiefly distributed to the body wall. The dorsal commissure is relatively heavy and closely applied to the dorsal wall of the rectum. In the median line it gives rise to a nerve that may be traced to a point near the dorso-terminal portion of the body. In position it corresponds to the nerve supplying the dorsal sense organ in other Solenogastres described in this paper, but no such well-defined sensory area appears to be present in this species.

In this species the paired gonad, without any special peculiarities, terminates rather abruptly at a point about as far forward as the hinder border of the atrial opening, and on the other hand passes by two relatively large ducts into the spacious pericardial chamber (Plate 11, fig. 1). From the lateral portions of a small recess at the posterior end of this cavity each coelomoduct arises, and after passing downward for a short distance then passes forward, gradually increasing in size until it reaches a position about level with the hinder tip of the gonad. Here it bends abruptly and coursing backward unites with the one of the opposite side, and as a short common duct makes its way to the cloaca.

Each canal commences its course with an epithelial lining essentially like that of the pericardial wall, being composed of low flat cells entirely devoid of cilia and lateral cell boundaries. These deficiencies are soon overcome, however, and there are evidences in some of the cells a short distance from the pericardium of a slight glandular activity. In proportion to the increasing diameter of the duct the cells show a greater width and height and the cilia become a strongly marked feature. This holds true for only a portion of the canal however for at a point slightly below the level of the lateral nerve the character of the lining changes abruptly. At this point the cells become high and columnar along the dorsal side of the tube and form a ridge, extending forward to the most anterior

turn in the duct. The cilia with which this part of the tube is provided are probably operative in driving the sex products toward the exterior. There are no evidences that they ever form a groove such as has been described in a few other species, and it must rather be supposed that both sex products travel much the same path. At the anterior sharp turn of the coelomoduct the ciliated ridge passes, so far as may be judged from sections, into a ciliated patch that occupies the anterior wall of the canal, and extends a short distance down the posteriorly directed section, corresponding to the shell gland in other Solenogastres. This patch, roughly circular in outline, is composed of low columnar cells provided with very long, powerful cilia. Posteriorly the cells of this region blend with others of the same general appearance, but without cilia, and filled with an abundant secretion in several cases in the act of being discharged. This glandular area is limited to a narrow girdle encircling the duct, and is sharply defined from the succeeding portions of the canal, whose walls are developed into numerous folds obscure at first but in the neighborhood of the cloaca of considerable height. The cells in all of this corrugated section, the shell gland of other Neomeniina, vary in height according to the size of the fold of which they form a part, but all agree in being relatively slender with central dense nuclei external to which the cytoplasm is filled with some glandular product of yellow tint. In the terminal section of the cloacal passage this substance is present in considerable quantities and at various points has made its escape in an unchanged condition into the neighboring duct.

Proneomenia hawaiiensis, sp. nov.

This species is represented by three individuals, one perfect and two mutilated. The first was dredged in the neighborhood of Kapuai Point off the western extremity of Kauai Island (Sta. 4001) at a depth of 230–277 fath. where the bottom consisted of coarse sand and the temperature was 44.3° F. The imperfect specimens were taken in the vicinity of Mokuhooniki Islet (Mokuo Niki), a small island close to the eastern border of Molokai Island (Sta. 3864) at a depth of 163–198 fath. where the temperature was 57.5° F. and the bottom consisted of shells and fine volcanic sand. All the specimens came in unattached and without any food in the digestive tract so that nothing is known of their mode of life.

The perfect individual measured 36 mm. in length and 2 in average diameter, and this proportion of 1 : 18 appeared to be the same in the imperfect specimens. The body (Plate 3, fig. 10) is elongated, tapering gently from the forward to the hinder end, and is slightly elliptical in cross section. A rusty red incrusta-

tion covered the entire animal save the anterior tip and the lips, where the color was light lemon-yellow.

As in other members of the genus the atrial opening is subterminal and presents the appearance of an elongated slit encircled by rounded lips. Immediately behind it the ventral furrow takes its rise and extends to the posterior end of the body where it becomes continuous with the subterminal cloacal opening. Sections show a well-defined dorsal sense organ with small surrounding spines (Plate 32, fig. 10) but owing to the debris encrusting the body this was not externally visible.

With the exception of the ventral furrow the body is covered by a relatively thick cuticle that must be an efficient means of protection and at the same time render the animal relatively sluggish. As usual innumerable calcareous spicules are imbedded in the cuticle, forming five or six irregular layers. These spines are of two distinct types; one, the larger and more abundant form with rounded extremities (Plate 37, fig. 5a) is placed more or less parallel with the hypodermis while the second (b) extends at right angles to it and projects slightly above the external body surface. Spines of somewhat this same general form are located along the ventral furrow and about the atrial and cloacal openings; but in their mode of development and owing to numerous intermediate stages it may be seen that they belong to the first class. A more detailed description of the position and development of the spines of this species is given on page 28.

The cuticle is penetrated also by many papillae whose arrangement and general appearance are shown (Plate 33, fig. 3). As Hansen has noted they appear like so many baloons situated immediately below the external surface of the cuticle and connected with the hypodermis by a slender fibre. This distal expanded part appears to consist of several cells each with basally placed nucleus and an outer vacuolated section which usually fuses with the corresponding part of the other cells. These elements pass without any sharp line of demarcation into the stalk that contains from four to six elongated nuclei and in turn unites without definite cell boundaries with a small number of cells of the hypodermis. In many cases delicate fibres may be traced from these hypodermal cells into the deeper tissues of the body, and at the anterior end of the animal they may occasionally be followed into close proximity to the ganglionic layer surrounding the atrial wall; nevertheless while appearances seem to favor the belief that these are nerve fibres and the papillae are sense organs the evidence is not complete.

The pedal gland is coextensive with the foot and consists of two long slender

bands of cells situated a short distance within the body on each side of the ventral furrow into which their secretion is poured. In the body proper the position, size, and number of the component cells in cross section is shown (Plate 14, fig. 3). This condition of affairs exists to the front end of the gonad where the gland cells become more abundant and of larger size, occupying approximately one fourth of the visceral cavity at the level of the posterior end of the radula. Their outlets still continue in the ventral furrow and in addition occur throughout the region of the anterior division of the foot, which contains extensive blood lacunae and may probably be protruded at times beyond the ventral furrow.

The anterior pedal gland abuts against the front end of the pedal gland proper and, occupying more than half of the space between the buccal mass and the body wall, extends as far forward as the brain. The main body of each of its cells consists of spongy cytoplasm containing an abundant secretion that stains faintly in Delafield's haematoxylin. The included nucleus is relatively very small, granular and very irregular in form. Several cells are usually grouped together and surrounded by a few connective-tissue fibres. Each cell is attached by a duct with the ventral furrow chiefly in front of the foot. All of the ductules of both pedal glands open between the cells of the ventral furrow.

The atrial opening leads into a cavity of relatively generous proportions (Plate 5, fig. 2) with walls abundantly supplied with sense organs of several different types. The most external of these, which I have termed the outer atrial ridge (Plate 14, fig. 1), presents the appearance of a low prominence situated just within the lips and encircling the atrium except in the mid line behind. Its cells are comparatively slender and in addition to the darkly staining and usually basally situated nuclei, they contain numbers of greenish yellow pigment granules. Lying in contact with the inner ends of these cells is an accumulation of ganglion cells forming an elongated mass coextensive with the ridge itself. From it nerve fibres may readily be traced to the sensory cells adjoining, and in an opposite direction large nerves occasionally pass inward, and soon become confused with the ganglionic elements attached to the bases of the cirri above. That this is a highly sensory structure there is no reasonable doubt, but to define its function more accurately is at present impossible.

Of almost identically the same length as the sensory ridge just described and directly in contact with its inner border is another inwardly projecting fold of much greater height and widely different character. It likewise encircles the atrium save on the posterior side where its free extremities unite with another ridge of corresponding height and appearance that farther within the body also

encircles the atrial cavity. The epithelial cells bounding these ridges (Mundleisten) are columnar, richly ciliated and besides the centrally placed spherical nucleus contain a small quantity of greenish yellow pigment. Within the ridges are a few connective and muscle elements and an occasional nerve fibre, all loosely arranged and permitting the entrance of multitudes of blood corpuscles that probably cause the distension of these organs.

The area bounded by these two sensory prominences is the cirrose region characterized by the presence of numbers of hollow finger-shaped projections each attached by its base and extending into the atrial cavity. The cells composing these organs differ to some extent in different specimens but agree in being low, non-ciliated, and charged with a considerable quantity of the usual greenish yellow pigment and a varying amount of some hyaline secretion that often covers their external surface. More slender elements, scant in numbers, occur among these ordinary cells; they may be sensory but some at least appear to be cells from which the secretion has recently been discharged. The cavity within each cirrus is usually very slender and is traversed by a muscle and nerve fibre. In very exceptional cases there are one or two blood corpuscles; but neither in this nor in other species of Solenogastres have I found any indication that these play an important part in the process of respiration. Beneath the cirri is a felt-work of muscle, connective and nerve fibres together with blood corpuscles and leucocytes beyond which is a mass of ganglion cells connected with the central nervous system and on the other hand with sense organs of the atrium and probably of the hypodermis.

A very short distance within the inner ridge the digestive tract narrows rather abruptly, the character of the epithelial lining changes radically, and since it marks the point of entrance of the dorsal salivary gland it may be considered the line separating the mouth and pharynx. According to such an interpretation the pharyngeal wall, lined with a relatively heavy cuticle, is thrown into a series of ridges that course more or less longitudinally throughout its entire extent. In the majority of cases the cells are high, with central oval nucleus and a slight secretion that had escaped at various points through some of the exceedingly minute pores passing through the lining cuticle.

The so-called dorsal, or accessory, salivary gland is attached to the dorsal wall of the pharynx immediately behind the brain (Plate 5, fig. 2). The cells composing it are one layer thick, and as the duct itself is short and unbranched the gland is necessarily compact and globular in form. The epithelial lining of the pharynx is continued inward to form the lining of the duct between whose

cells the secretion is discharged. The cells of the gland are comparatively large, with small nuclei and an abundance of a lightly staining secretion, and are grouped into several clusters separated from each other by a small amount of connective tissue.

The paired ventral salivary glands are long tubular unbranched structures opening into the pharynx on each side of the front end of the radula. Their position and general appearance are represented (Plate 14, figs. 7, 9). Each constituent cell is high and columnar in form, composed of vacuolated cytoplasm and possessed with nuclei ranging from spherical to slender spindle-shaped forms correlated with different stages of glandular activity. The secretion within the main duct is finely granular and has only a slight affinity for logwood dyes.

In this species the radula is relatively well developed and is located as in other members of the genus. The teeth are formed by odontoblasts of the usual high columnar type characteristic of the Chitons and prosobranchs and are of the form represented (Plate 34, fig. 13). All the teeth are of essentially the same form and number not less than from thirty-eight to forty-five in each transverse row. There is no indication of a median tooth so far as the sections show but each tooth adjacent to the mid line is somewhat smaller than its fellows (Plate 34, fig. 13). In some species of Solenogastres the teeth are reported to be merely thickenings of a continuous cuticular plate, but in this species they are clearly distinct, a well-defined suture not only separating each tooth from the others but from the basal plate as well.

Immediately in front of the radula and somewhat covered by its forward border are two areas of high columnar cells (Plate 34, fig. 2) that are more or less sunken in a well-defined sheath. In another place (Heath '04) it has been shown that these organs probably correspond to the subradular organ in the Chitons and some of the prosobranchs. Their innervation is discussed in the section on the nervous system.

The usual relation of pharynx and stomach-intestine are shown (Plate 5, fig. 2). In another specimen the anterior dorsal coecum is considerably more developed and there is also a small ventral one that extends forward between the salivary glands. A short distance behind the pharynx the cells of the digestive tract shade gradually into the relatively high pyriform hepatic cells of the stomach-intestine. There are strong evidences that the distal part of these cells loaded with secretory products separates from the remaining nucleated portions and dissolves in the alimentary tract and that the process is repeated indefinitely, the basal nucleated parts developing anew the glandular distal portions.

Upon reaching the front end of the cloacal passage (slime gland) (Plate 14, figs. 5, 6) the alimentary canal becomes crescent-shaped in cross section, the concave surface being in contact with the gonad. Before reaching the cloaca it becomes elliptical and the epithelial lining is developed into longitudinal folds that persist to the anal opening.

The heart is irregularly cylindrical in form, lacks any clear subdivisions and is attached to the dorsal wall of the pericardium. From its anterior end the dorsal aorta takes its origin and coursing forward between the gonad and the body wall finally makes its way into the roughly defined head cavity. At irregular intervals it gives rise to small ventral branches that pass between the halves of the reproductive gland and enter a sinus lying along the under side of the organ. From this vessel lateral branches extend around the sides of the gonad and open into the visceral cavity dorsally. This relation of aorta and gonad continues as long as any trace of the latter exists, and anterior to this point the aorta gradually enlarges and finally in the neighborhood of the brain passes into the "head cavity." This last named space is not bounded posteriorly by a septum, but is well defined by the front end of the pedal gland through and around which the blood passes backward by small channels into the visceral cavity proper. This large sinus surrounding the digestive tract is subdivided into two roughly defined spaces, a relatively large sinus lying beneath the intestine and a very much smaller one located between it and the foot. At irregular intervals these two communicate and small lateral canals also connect the pedal sinus with the main section of the visceral cavity. The latter also communicates with the ventral intestinal sinus by fairly well-defined lateral canals that occupy positions between the gut pouches. In the neighborhood of the cloacal passage these minor sinuses unite with the larger and the blood, that has travelled backward in all of them, makes its way dorsally to open into the hinder end of the heart.

In a foregoing account (Heath '04) the nervous system of this species has been described and in this connection it is only necessary to mention the more prominent features. As is represented (Plate 5, fig. 2), the brain is situated in a depression immediately in front of the dorsal salivary glands. Anteriorly it develops six nerves whose branches supply in large measure the sense organs of the buccal wall and probably the hypodermis and the musculature of adjoining regions. Posteriorly it gives rise to three pairs of nerves, the lateral, pedal, and labio-buccal connectives. The lateral cord almost immediately takes up its permanent position at the sides of the body; the pedal passes downward and

backward to unite with the pedal ganglia that occupy the usual ventral position; while the labio-buccal connectives pass backward along the sides of the pharynx and unite with the labio-buccal ganglia that are placed at the sides of the radula. About mid way between the brain and ganglia the labio-buccal connectives are united by a commissure (dorsal buccal) that passes across the dorsal side of the pharyngeal wall, while a second (ventral buccal) passing over the radula unites the buccal ganglia. Each of these last named nerve masses, connected by the well-known commissure dorsal to the radular sac, gives rise to a prominent nerve that passes inward and unites with a ganglion situated near the base each of the subradular organs mentioned in connection with the radula. Each subradular ganglion is in turn connected with a commissure imbedded in the tissue beneath the pharynx. The relations of these ganglia and the attendant sense organs is essentially the same as in the Polyplacophora. They are much more concentrated in the latter group but the various elements may be readily homologized.

Through the body proper the pedal and lateral cords are united by connectives corresponding roughly to the number of gut pouches. About the same number of commissures also unite the pedal cords. These connectives and commissures disappear about the middle of the slime gland and a short distance beyond this point the pedal cords disappear apparently without forming a posterior connective (Plate 13, fig. 4). The lateral cords on the other hand pass into the posterior ganglia that give rise to many nerves supplying the surrounding tissues and are united by a strong commissure dorsal to the intestine. In the mid line this commissure develops a nerve that supplies the dorsal sense organ.

The dorsal sense organ is located on the mid dorsal line a short distance from the hind end of the animal. Sections show that the cuticle in this region is almost wholly lacking and that the neighboring spines bend over and protect the otherwise naked sensory area. In each specimen the spines were much worn and the upper part of the sensory hollow was filled with debris so that no outward sign of this organ was visible. In one individual, probably abnormal in this regard, there were two dorsal sense organs, one a short distance in front of the other in the mid line. The posterior one corresponds most closely to the single one of the other individuals and will be first described.

The cuticle over the sensory region is almost wholly absent and the hypodermal cells, that ordinarily are small and distinct, become clearly defined, columnar, and depressed below the general level of the hypodermis. To the

bottom of this hollow are attached a group of ganglion cells that connect in turn with a nerve from the postpallial commissure. Several muscle fibres are also united to the base of this organ. Judging from appearances the pressure of the blood beneath causes an eversion of the cells of the sensory pit bringing them to the level of the general body surface while the contraction of the muscle fibres produces their withdrawal and, if of sufficient strength, the overarching of the surrounding spicules.

The anomalous sense organ mentioned previously as occurring slightly in front of the dorsal organ proper consists of two sensory pits in all essential respects like the one just described. They are separated by a ridge (Plate 32, fig. 10) on which the spines are relatively small and the hypodermal epithelium only slightly different from that found over the body elsewhere. Nerves from the post lateral (pallial) commissure pass to the depressed area that thus appears to be the sense organ proper.

As in other Solenogastres the hermaphrodite gland is in the form of two greatly elongated sacs closely appressed along the mid line and extending nearly as far forward as the brain. As usual the ova are developed along the inner wall while the spermatozoa are produced more externally. In the region of the heart each half of the gonad becomes narrowed to a small duct that communicates with the front end of the pericardium, which in one of the specimens was of large size and filled with sex products.

From the postero-lateral borders of the pericardium the coelomoducts arise (Plate 13, fig. 4) as relatively slender tubes, and coursing forward and downward make their way by a fairly direct course to a point near the front end of the shell gland into which they open. Each canal is in the form of a greatly elongated spindle lined throughout the first part of its course with low flat cells, having indistinct boundaries like those of the pericardial cavity. In the middle enlarged section they attain a greater height becoming nearly cubical, a shape they retain throughout the remainder of this section of the genital canal.

The shell gland or slime gland is a comparatively voluminous organ roughly U-shaped in form (Plate 11, fig. 5). Anteriorly each limb communicates with the spiral seminal receptacle and the section of the gonoduct just described while posteriorly both unite and enter the cloaca by a comparatively narrow opening. In striking contrast to the low epithelium of the dorsal limb of the genital canal the lining cells of this section possess clearly defined walls, are high and slender, and are glandular in character. Those in the neighborhood of the seminal receptacle differ considerably in the nature of their secretion from those of the

succeeding portions. With the exception of a small mass of protoplasm containing the spherical granular nucleus the cytoplasm is charged with a product apparently muciform, staining intensely with logwood dyes. In many cases the material has been discharged leaving a relatively spongy protoplasmic matrix. When relieved of their load the cells show no sign of degeneration but continue to elaborate the secretion which forms as minute granules uniformly distributed throughout the protoplasm. As these increase in amount they unite, finally becoming one confluent mass that almost completely fills the cells. In the only other specimen which was sectioned this portion of the gonoduct is composed of cellular elements of the same appearance, but the secretion is hyaline and unaffected by Delafield's haematoxylin, a condition of affairs due in all probability to a different phase of glandular activity.

In both specimens these cells of the anterior third of the shell gland blend rather gradually with those of the succeeding section of the duct. As Hubrecht notes in *Proneomenia sluiteri* the cells are very slender elongated elements with basal nucleus and a secretion, developing at first in the form of minute granules which subsequently fuse and form particles of larger size until one great droplet occupies almost the entire cell often crushing the nucleus into an almost indistinguishable mass. It is worthy of note that all the cells in a fairly well-defined area are usually in the same stage of activity, perhaps discharging their burden while those of neighboring regions may be entering into the first stages of the process. In many cases where the secretion has recently been discharged it acts as a highly viscous fluid that only gradually undergoes liquifaction and fills the lumen of the cloacal passage.

Proneomenia insularis, sp. nov.

This species is represented by a small portion of the anterior end of one individual including the radula and the comparatively long ventral salivary glands.

The specimen was found in the bottom of a jar containing some alcyonarian corals that were dredged near Bird Island (Sta. 4157) at a depth of 762–1,000 fath. where the bottom consisted of white mud and foraminiferous sand with a temperature of 38°. In external appearance and especially in the relations and structure of the cirri, atrial ridges, the radula, salivary glands, and other of the more important organs this species shows a very close resemblance to the species of Proneomenia just described; accordingly I have very little hesitancy in placing it in this genus. The present fragment, cylindrical in cross section

save for a slight flattening of the ventral surface, measured about 1.5 mm. in diameter and terminated anteriorly by a rounded extremity (Plate 8, fig. 4). There is no crest. Its enveloping cuticle, of the usual yellow color, is comparatively thick and contains large numbers of tapering spicules with rounded ends (Plate 37, fig. 16). Another type of spine occurs in the deeper layers of the cuticle in the form of relatively short basally truncated bodies which are in contact with a stalked cell of the hypodermis. In the case of the larger spicules of this character the sharp distal point may protrude freely above the cuticle.

The anterior pedal gland is relatively voluminous, extending forward as far as the cirrose area, posteriorly to the front end of the oesophagus and filling nearly all of the visceral space between these two boundaries. As has been noted in other species of the genus this gland opens separately into a comparatively large space situated behind the mouth opening and continuous with the front end of the pedal furrow. Posteriorly this organ passes without a sharp line of demarcation into the pedal gland proper that holds the same relation to the animal as in the preceding species, but in bulk and in size of its cells it is probably twice as large. Behind the opening into which the anterior pedal gland pours its secretion the foot commences as a low median ridge that gradually assumes its full size though this is considerably short of that of the foregoing species.

The opening of the atrium holds the same position and is of the same relative size as in *P. hawaiiensis* (Plate 8, fig. 4). The ridges and the cirrose area are likewise very similar in the two forms. The ciliated ridges are not so high in this species owing possibly to the amount of contained blood and the cirri, somewhat more slender than in the foregoing species, are united by their bases into groups of two or three.

The junction of the atrial cavity and the pharynx is characterized by a ridge similar to that of the preceding species, but is not farther marked by the presence of a dorsal salivary gland. A very few relatively large cells are situated among the nerve fibres passing out from the brain, but while they are in the correct position for the unpaired gland no ducts have been discovered.

The paired salivary glands present the same general appearance as in *P. hawaiiensis*. In the present specimen each organ extends from its opening at the sides of the forward end of the radula backward twice the distance from the front end of the animal to the opening of the salivary duct. Beyond this point the remaining portions of the body are missing. The cells are of the usual high columnar type and are more vacuolated than in any specimens of the preceding species.

After extending backward for about half its length the pharynx bends abruptly upwards and unites with the stomach-intestine. In the angle thus formed is placed the radula that is considerably shorter than in the foregoing species. The teeth also are much smaller though of somewhat similar shape and judging entirely from longitudinal sections there are probably not less than twenty-eight transverse rows with at least twenty-four teeth in each row and possibly more. On the other hand the radular supports, in the form of several transverse rods of compact connective tissue, are more highly developed. The relation of the pharynx and the stomach-intestine are sufficiently shown (Plate 8, fig. 4). The anterior coecum, the gut pouches, and the digestive cells are also essentially like those of *P. hawaiiensis* and require no comment.

In connection with the circulatory system there are no unique characters. Every blood space was crowded with corpuscles, spherical in form, with dense nuclei and cytoplasm, colorless after treatment with Delafield's haematoxylin, and containing several refringent granules.

In this species the brain is of medium size, its greatest diameter equaling one eighth the average diameter of the body, and is situated some distance behind the union of the pharynx and mouth. As usual three pairs of nerves pass from its forward and lateral regions to the front part of the body, becoming lost to view in the region of the cirri or more laterally among the body muscles. The connectives passing backward are completely ensheathed in the anterior pedal gland whose granular substance renders it very difficult to follow them to their destination. It has been possible to trace the relatively large pedal fibres to the pedal ganglia, and the lateral connectives to their position along the sides of the body, but the labio-buccal connectives are exceedingly difficult to differentiate. However with the aid of high magnification their course has been traced beyond question to the ganglia situated on each side of the pharynx about the level of the radular supports. Each is characterized by a much elongated spindle shape, the connective uniting with its anterior end and the ventral commissure attaching posteriorly. This latter nerve arches over the dorsal side of the radula and otherwise presents the usual appearance. A dorsal buccal commissure, subradular system, and labial commissure were not found.

Immediately in front of the radula is a ridge of columnar cells that may correspond to the subradular organ. In several sections it is also possible to distinguish fibres that have the peculiar refraction of other undoubted nerves; yet in spite of persistent effort it has not been possible to determine their relations.

Three pedal commissures have been proven to exist and eight palliopedal connectives, all with the usual relations.

The paired gonad extends forward to a point slightly behind the level of the hinder end of the radula supports. Anteriorly its cells are entirely male, minute ova appearing only in the most posterior part of the fragment.

Driomenia pacifica, sp. nov.

Three individuals of this species were taken off the southern end of Japan, two from Ose Zaki (Sta. 3716) at a depth of 65–125 fms. and one from Kagoshima Gulf (Sta. 4935) at a depth of 103 fathoms. All were imbedded in a mass of hydroids belonging to the genus Sertularella. The body is of uniform diameter, measuring 1 mm. by 9 mm. in length. The color in alcohol was a yellowish white.

No dorso-terminal sense organ has been discovered.

The cuticle is thick and contains an innumerable number of hollow spicules of varying sizes but with the general form represented in Plate 39, fig. 5. The usual hypodermal cells are not especially favorable for study, but on the other hand those of the papillae (Plate 38, fig. 10) are exceptionally clear. In the distal portion of each papilla the cells are spindle shaped, usually compact and finely granular, and appear in many cases at least to be continuous with a slender fibre which traverses the stalk and may be followed readily into the tissue beneath the hypodermal layer. Beyond this point their course cannot be determined with certainty and accordingly there is no clear evidence as to whether they are muscle or nerve.

The anterior pedal gland, occupying the customary position, is composed of the usual pyriform cells of average size. Posteriorly it passes without any change, except a decrease in the number of cells, into the posterior pedal gland which accompanies the foot throughout its entire extent. The outlet of the anterior pedal gland (Plate 38, fig. 1) is a plain walled, globular cavity heavily ciliated. Posteriorly two lateral and one median fold arise on its walls and soon unite to form the foot which continues to the cloacal opening though the two lateral folds become of small size.

The atrial chamber, distinctly separated from the remainder of the digestive tract by a spiculose ridge, is a cavity with walls fashioned into the usual sensory organs. The inner and outer ridges are moderately low, horseshoe-shaped ciliated folds nearly encircling the chamber and bounding the cirrose area. Each cirrus is very slender, without a distinct cavity and is usually united at its base with one or two others.

The true mouth opening is borne on the summit of a low yet broad proboscis which is separated by a very narrow spiculose ridge from the outlet of

the anterior pedal gland. From external view this proboscis is not visible, the ventral furrow appearing to extend to the atrial chamber. The mouth leads into a slender tube, with irregular longitudinal folds, and becoming gradually larger as it courses dorsally it opens into the stomach-intestine. About midway it connects with two short ducts from the salivary glands wedged between the stomach-intestine and the anterior pedal gland in the general position represented (Plate 38, fig. 1). Each salivary gland cell is pyriform, slightly vacuolated with distinct compact nucleus and unites with the main outlet by means of a very slender ductule.

The anterior coecum and the adjoining section of the gut, is a plain walled tube lined with the usual vacuolated, granular digestive cells. More posteriorly lateral pouches of irregular form appear (Plate 38, fig. 1) and may be found at fairly regular intervals as far as the anterior end of the pericardium. Here the canal rapidly narrows, becomes circular in outline (Plate 38, figs. 7, 9) the epithelial lining is reduced in height and by a slender pore it opens into the cloacal chamber whose form and relations are represented (Plate 38, fig. 2). It may be added in this connection that the walls of the cloaca are devoid of folds, glandular appendages, or modifications of any definite character.

The pericardial cavity is of moderate size but in one respect differs from that of any other Solenogastre. Immediately behind the opening into the gonad the pericardial wall forms two latero-ventral outpouchings of considerable length (Plate 38, figs. 2, 7). The component cells are low columnar in form, without definite signs of glandular activity and contain relatively large dense nuclei. It is impossible to determine their function though they may be seminal vesicles since cells of the same general appearance compose the lateral pericardial wall and connect these diverticula with the inner openings of the coelomoducts.

The heart is of average size and consists of two distinct divisions. The anterior one, without any sharp boundary line is continuous with the aorta which, throughout its entire length, is a tube of more than usually great size. Its connections with the gonad and the anterior end of the body are normal as are those of the visceral sinus. Large blood spaces occur about the cloacal cavity and as the walls of the latter are thin the exchange of gases may readily take place at this point. The blood corpuscles vary considerably in shape, in some cases being similar to the elongated type found in Strophomenia and at other times appearing almost globular. This may be a *post mortem* effect but the cells are very well preserved.

The nervous system is difficult to trace and accordingly has been examined in its broader features only which show it to be of the usual type.

The single specimen examined is sexually mature and the reproductive gland extends as far forward as the level of the salivary glands. While the eggs are attached as usual to the median wall of the gonad the sperms develop in lateral pouches. In the posterior end of the body these crypts are of large size, extending in some cases far down the sides of the intestine, and they are connected with the gonad by small pores (Plate 38, fig. 2).

The coelomoducts arise as relatively small tubes from the posterior border of the pericardium and extend forward to the region of the seminal receptacle where as usual they unite with the shell gland. The lining epithelium is low, the cells cubical and ciliated and without indications of being glandular. Each seminal receptacle is a comparatively large club-shaped sac provided with several small outpouchings especially on its distal extremity. In these small pouches multitudes of spermatozoa are attached to the lining epithelium which is composed of slender columnar cells.

The shell gland is in the form of a thick set **Y** and as may be seen, Plate 38, it contains a cavity of moderate size. The greater number of gland cells are of one type, high columnar elements containing, large numbers of spherical granules. In the neighborhood of the opening into the seminal receptacle these are associated with a small number of cells containing, after treatment with Delafield's haematoxylin, a homogeneous violet colored substance. In close proximity to the opening into the cloacal chamber the dorsal wall of the gland contains a considerable number of cells, which secrete a coal black substance when treated with the above mentioned stain. All of these glandular elements are in contact with slender supporting cells containing mesially placed spindle-shaped nuclei.

Dorymenia acuta, sp. nov.

Eleven specimens of this species were dredged in the vicinity of the Santa Barbara Islands, off southern California, at depths ranging from 302–638 fathoms. The three largest specimens measure 35 mm. in length by 1.25 average diameter, with one exception having a thickness of 2.25 mm. The two smallest individuals are 14 mm. in length by 1 mm. average diameter, and with one exception, a slightly spindle-shaped individual, all of the specimens are slender and of about uniform diameter throughout (Plate 3, fig. 11). Their color varies from a grayish white, where the brick-red color of the liver shines through the cuticle, to light lemon-yellow. The head is rather sharply pointed, and but slightly

differentiated from the body proper, which posteriorly terminates in a very pointed extremity as in *Proneomenia weberi* Nierstr. The atrial opening is relatively small, subterminal and surrounded by tumid lips which separate it from the ventral furrow. As noted in a succeeding paragraph, the anterior pedal gland is highly developed, but its outlet is not especially modified externally. Posteriorly the pedal groove is continuous with the cloacal cavity. The cloacal opening is relatively large, ventral and is overarched by the posterior pointed end of the body, whose lateral margins are involuted, but may perhaps be flared occasionally to expose the genital spicula, the appearance of the hinder end of the animal resembling at such a time *Ichthyomenia ichthyodes* Pruvot.

A well-developed dorsal sense organ (Plate 15, fig. 11), visible in sections only, is present a short distance from the posterior end of the body, and is supplied with special nerves and blood sinuses as in *P. hawaiiensis.*

The cuticle investing the body is relatively thick (Plate 33, fig. 4), and is developed by a hypodermal layer in which the component cells are of small size. Those not instrumental in the formation of the spicules or papillae are more or less cubical in form and consist of vacuolated cytoplasm in which the nucleus, usually spherical, holds a central position. At various points the nuclei are dense and elongated and may possibly belong to sensory cells.

The spicules are hollow needle-like structures (Plate 37, fig. 10), those of the alternate layers crossing the others almost at right angles. In their formation no points of especial interest appear. As usual several cells take part in the process as in *P. hawaiiensis.*

The papillae are of average number and present the appearance represented (Plate 33, fig. 4). Three or four spindle-shaped nuclei occur in the slender fibrous stalk while from five to seven are present in the swollen distal portion. In this last named situation the nuclei are frequently of two sizes, small dense bodies, and one or two of twice their size with a more vesicular appearance. Judging from many sections both the number and character of these elements are due to different stages in the development of the papillae. In advanced stages these latter organs may open to the exterior and become so filled with debris that the cellular elements save those of the stalk, become obliterated. This, however, is undoubtedly an abnormal condition and marks the close of an active functional existence on the part of the papilla.

The anterior pedal gland, as in various other species of Neomeniina, is a voluminous organ extending anteriorly as far as the brain, posteriorly as far as the forward border of the radula and filling practically all of the space between

the gut and the body wall. The cells, where not compressed, are pear shaped with a diameter ranging from .0185–.0351 mm. In the early stages of their existence the cytoplasm is vacuolated and not affected with haematoxylin but with the assumption of glandular activity the secretion, in the form of fine darkly staining granules, appears in the peripheral portions of the cell gradually filling the more central portions with the exception of the small, and at this stage, much shrunken nucleus. Delicate ducts, as usual, lead from the cell body to their intercellular opening into the anterior end of the pedal furrow.

From external view the opening of the anterior pedal gland is not marked by any noteworthy peculiarity, but from sections it may be seen that the pedal groove soon expands inwardly into two extensive lateral diverticula (Plate 15, fig. 1), whose anterior walls, in some specimens, are thrown into low folds and more posteriorly are supplied with very heavy cilia, ranging from one to three times the length of the supporting cell. Along the median dorsal line a large fold exists which more posteriorly is continuous with the foot. Everywhere throughout this fold and over the anterior folds of each crypt the secretion makes its exit in the form of a very finely granular almost homogeneous substance and after treatment with haematoxylin of a slightly pinkish tint.

The posterior pedal gland is also well developed and consists of a rod of cells on each side of the mid ventral line continuous in front with those of the anterior pedal gland with which they are identical save for their slightly smaller size. Posteriorly they gradually diminish in bulk and number, and in the region of the cloaca finally disappear.

The foot consists of very little more than a V-shaped epithelial fold, the included muscle and connective tissue being very scanty, and entirely devoid of blood sinuses or at all events those of sufficient size to include blood corpuscles in preserved material. Throughout its entire extent it is accompanied by two small epithelial ridges which are to be considered special modifications of the hypodermis. The inter-cellular openings of the pedal gland occur in the angle formed by these ridges and the foot.

The atrial opening, holding the usual subterminal position, leads into a cavity possessing essentially the same relations as in various species of Neomenidae. Like *Proneomenia hawaiiensis*, for example, there are two conspicuous ridges surrounding the cirrose area, and external to the outer buccal ridge a low elevation encircles the cavity save in the mid line posteriorly. From this elevation numerous delicate fibrils may be traced to a rod-like accumulation of ganglion cells coextensive with the ridge itself. On the other hand these

nerve cells connect by relatively large nerve bundles with the ganglia located near the bases of the cirri.

Of the ciliated ridges (Mundleisten) the more external are in the form of two elevations which approach each other very closely in front and behind, at which points they become low and inconspicuous though in their mid section they are comparatively high. The inner ridge has the form of a horseshoe, the free extremities connecting posteriorly with the ends of the outer ridge.

This inner prominence is relatively short yet high, and like the outer contains a loose meshwork of muscle and connective-tissue fibres among which are numerous blood corpuscles. The cells composing them present much the same appearance as those of the outer low elevation described in the preceding paragraph. Practically all are slender and contain small amounts of pigment and elongated nuclei. Nerve fibres may be followed into the ridges which thus seem to be sensory. In *P. hawaiiensis* these cells are richly ciliated, but in this species all traces of cilia are absent and, it may be added, the material is excellently preserved.

Within the cirrose area and lying behind the innermost ridge the atrial wall in the mid line is developed into a fold, of large size, which is closely packed with multitudes of blood corpuscles. If the buccal ridges serve as respiratory organs, as some authors would have us believe, this structure is certainly more efficient since it is not only voluminous but its epithelial covering is not more than one third as thick as that of the general atrial cavity.

The cirri are prominent structures in this species, being not only numerous but of considerable length and calibre. Each is composed of cubical or low columnar cells filled to a considerable extent with the usual yellowish pigment which more or less conceals the small centrally placed spherical nucleus. At various points these organs may arise singly from the buccal wall, but usually the bases of from four to six are fused, and into this stalk muscle and occasionally nerve fibres may be traced. The cavity of the single cirrus is usually so small that the relation of these fibres remains unknown and, it may be noted, effectually blocks the entrance of blood cells, so that these organs are rather to be considered retractile sensory organs with little respiratory function.

A short distance behind the cirrose area the pharynx originates as a tube with somewhat smaller diameter than the atrial cavity. However, immediately behind the region of the brain the canal from external view expands considerably, but sections of this region show that a great fold develops in the pharyngeal wall which it entirely encircles reducing the cavity to a crescentic slit (Plate 15,

figs. 1, 7). Numerous muscles inserted in the tissue of the fold and on the other hand to the body wall doubtless serve to dilate the canal when the animal is in the act of feeding. Immediately behind this fold, and therefore in the region of the radula, the canal becomes much wider but more posteriorly again narrows and by a comparatively small opening communicates with the stomach-intestine. Throughout the entire extent of the pharynx its epithelial lining is thrown into numerous longitudinal folds, especially in the neighborhood of the radula where they become wavy and in sections present a most complicated appearance. In general the cells of the pharyngeal epithelium are low columnar elements devoid of cilia and overlaid with a clearly defined cuticular layer.

Two sets of salivary glands are present, a ventral pair and a group of cells imbedded in the large fold just mentioned. The cells of the last named gland, which is probably the homologue of the dorsal salivary gland of several other species of Solenogastres, are not grouped compactly as in *P. hawaiiensis*, for example, but are scattered throughout the tissue of the fold and open by separate pores over its entire extent. All the cells are pyriform and in early stages are composed of a finely vacuolated cytoplasm in which the secretion ultimately makes its appearance in the form of distinct granules of comparatively large size. These rarely accumulate to a sufficient extent to hide the nucleus but make their way by well-defined ducts to open by intercellular channels into the pharyngeal cavity.

The ventral salivary glands open into the pharynx at the sides of the extreme tip of the radula, and in the form of tubular outgrowths extend backward for a distance of 3.5 mm. As may be seen (Plate 15, fig. 2), the ducts are of large size and are bounded by slender cells densely filled with a secretion having much the same appearance as that developed in the dorsal set.

The radula is of the polystichous type, and judging wholly from sections consists of 48–51 rows with twenty-two teeth in each row. All the teeth are of essentially the same shape (Plate 34, figs. 7, 11) and size with the exception of those on each side of the mid line which appear to be slightly smaller. A very thin yet clearly defined basement membrane is present.

The radula sac rests upon a support consisting of a series of globular cells of which two are of relatively large size and are located symmetrically on each side of the mid line. All of these contain nuclei and a finely granular cytoplasm, which in the larger cells is usually greatly shrunken. To these supports numerous muscles attach, but from sections it is most difficult to describe their relations and define their function.

The matrix cells of the radula are comparatively small and the teeth numerous so that an accurate determination of the development of the teeth and basement membrane is difficult. Odontoblasts, holding the ordinary position and with the usual appearance are present and numerous enamel cells arise from the bottom of the radular sac. These latter elements may be traced forward a short distance among the newly developed teeth where they disappear. The cells responsible for the formation of the basement membrane are not unlike the odontoblasts all of which blend with the epithelial cells of the ventral side of the radular sac. In all essential respects therefore the development of the radula in this species is not unlike what exists in *Limifossor talpoideus*.

Immediately behind the opening of the pharynx into the intestine the walls of the latter develop a circular fold (Plate 15, fig. 7) which in life may be less contracted and serve as a valve. Anterior to it the intestinal coecum extends as far forward as the brain. It is almost wholly devoid of diverticula, though its low epithelial lining is thrown into numerous small folds on its ventral surface. Slightly behind the valve-like fold just mentioned the intestine proper arises, characterized by diverticula of almost mathematical regularity lined by the usual high club-shaped digestive cells, except underneath the gonad where the intestinal epithelium loses its glandular character and its low columnar cells support a coat of cilia. This state of affairs continues to the front end of the coelomoducts where the canal rapidly decreases in diameter and becomes ciliated throughout. Making its way to the dorsal side of the animal it passes between the pericardium and gonoduct to open into the cloacal chamber.

The pericardial cavity is a comparatively large space whose general shape and relations may be determined from Plate 6, fig. 4. The cells composing its epithelial lining are indistinct in outline, yet, judging from the nuclei, are more numerous than in any other species of Solenogastre described in the present paper. The heart also is of large size (Plate 15, figs. 4, 6) in both specimens which were sectioned, and very clearly consists of an auricle and ventricle. The first named division is much distended and the walls are thin and delicate, consisting externally of an epithelial sheet resembling that lining the pericardium, internally supported by a few muscle fibres. These form a loose meshwork from which occasional fibres pass across the auricular cavity to be inserted elsewhere in the wall. The long, sharply defined median dorsal sinus, extending from the posterior end of the body, enlarges as it passes forward and enters the auricle on its posterior border. As usual the ventricular walls are of greater thickness and the spaces formed by the interlacing fibres relatively small and filled with groups

of corpuscles. Anteriorly it passes into the aorta which, passing between the two widely separated ducts from the gonad, becomes a vessel of large diameter.

The vessels to the gonad, and the exit of these into the visceral cavity and the communication of the dorsal sinus with the numerous channels in the head region are of the usual type. The sinuses of the head are relatively small yet may readily be followed through the anterior pedal gland and about the buccal wall to a small median ventral sinus situated above the outlet of the anterior pedal gland. Above the forward end of the foot this median sinus widens greatly, and during its journey to the posterior end of the body communicates here and there with the visceral sinus and at various points is divided horizontally by a muscular septum, thus forming two fairly complete sinuses one above the other. In the region of the coelomoducts these channels become sharply defined, though as they approach the cloaca, the ventral one, in frequent communication with the dorsal, gradually diminishes and at the termination of the foot vanishes completely. The remaining ventral sinus has likewise greatly decreased in size in this same region, and communicating frequently with the outlying visceral cavity disappears immediately in front of the cloaca. At the sides of the cloacal cavity and posterior to it the blood probably passes backward in the ventral half of the body, and by means of numerous channels passes into the dorsal half where it is transferred to the heart by several lacunae, the median dorsal one being most clearly defined. The corpuscles are about two thirds the size of those of Proneomenia which otherwise they closely resemble (Plate 35, fig. 13).

It will be seen (Plate 6, fig. 4 and Plate 9, fig. 2), that the coelomoducts arise from the postero-lateral borders of the pericardium by relatively large openings, and extending forward as far as the anterior extremity of the heart communicate by a narrow canal with the conical seminal receptacle, and by a larger opening with the last section, of larger calibre, which unites with a corresponding tube of the opposite side and by a single median opening communicates with the cloacal cavity. Immediately beyond its inner opening the epithelial lining of each duct is thrown into prominent ridges composed of slender ciliated cells in which there are faint traces of glandular activity, which may possibly become more pronounced during the breeding period. Half way to the seminal receptacle the ridges disappear and the cells become lower, more cubical, and apparently are possessed of cilia. Furthermore throughout this same section of the canal some of the cells of its outer half become much elongated and form strands which

bridge the cavity. In the neighborhood of the seminal receptacle these are numerous but what their office may be it is difficult to conjecture.

The seminal receptacle is a thin-walled subconical sac provided with very slight internal folds and composed of low cubical cells which bear no trace of cilia nor secretory products. During the time it is filled with sperms, however, the cells become more or less liquified, the nuclei relatively large and pale after treatment with haematoxylin and great numbers of spermatozoa become imbedded in their substance. It unites by means of a short narrow canal with the coelomoduct at the point where the first and second sections meet.

The second section of the coelomoduct, or shell gland, is a tube of comparatively large size (Plate 15, figs. 4, 6). In the anterior third its walls are thin, almost devoid of folds and the cells composing it vary from cubical elements to others of low columnar form, if the animal be immature or out of the breeding season. As this last mentioned time approaches the cells become greatly thickened and the meagre secretion becomes abundant, filling the cell as a dark, almost black, substance like that of the muciparous gland in many molluses. This condition of affairs continues along the mid ventral line of the duct for a considerable distance posteriorly. The same modifications occur in the succeeding portions of the coelomoduct, but as the time of sexual activity approaches the cells become greatly elongated, are thrown into large transverse folds and are filled with a faintly yellowish secretion which at other times is scarcely visible.

In this species, as in *P. weberi*, two genital spicula are present and of large size (Plate 6, fig. 4). Each is inserted in a deep sheath, a diverticulum of the wall of the cloacal cavity, which extends forward and slightly upward to a point about level with the base of the seminal receptacle. The cells of the distal extremity, which are probably the spicule-matrix cells, are very slender elements (Plate 15, fig. 10), with dense spindle-shaped nuclei imbedded in an almost homogeneous cytoplasm having somewhat the appearance of the odontoblasts of various molluses. Throughout the remainder of the sheath, especially on its inner half, the cells are considerably smaller and their distal portion appears to be more or less cuticularized (Plate 15, fig. 5).

Two powerful sets of muscles, the retractors and protractors, attach to the sheath (Plate 9, fig. 2). The first named consists of a large number of minor bands inserted in the distal end, and on the other hand to the body wall, after having spread out fan-like, a short distance anterior to the seminal receptacle. The protractors are more numerous and attach at various points within a narrow

zone immediately behind the retractors. On the other hand, after passing backward, the various groups of fibres become attached to the body wall or to the cloacal wall in the neighborhood of the opening of the spicule sheath. Numerous other strands occur in this region whose function it is to widen the cloaca, enabling the spicule to be exposed while others bring about a counter movement. Those active in the first operation consist of many bands passing radially from the wall of the cloaca to become inserted in the body wall, and others which pass from the cloacal wall anteriorly to blend with the somatic muscles. The remainder, responsible for the reduction of the cloacal cavity, comprise many fibres which attach to the walls of the cloacal cavity, and passing backward unite with the body wall on each side of the forward border of the cloacal opening.

A pair of curious vesicles, irregular in form but of comparatively large size, occur one on each side of the body wedged in between the cloacal wall, spicule sheath, and coelomoduct and, as sections show (Plate 15, fig. 4), they are separated from each other by a thin vertical wall. On the posterior face of each a short slender tube communicates with the cloaca (Plate 9, fig. 2). In immature individuals or those not sexually active the walls are comparatively thin, and are composed of cells cubical or low columnar in form without any distinct signs of glandular activity; but as the breeding season approaches the walls become much thickened and each cell develops some substance which gives it a longitudinally striated appearance. This material remains unstained in haematoxylin and as it forms crowds the nucleus to the distal end. There is some evidence, though scanty, that this secretion is poured into the diverticulum and there becomes transformed into a darkly staining mucus-like substance which everywhere lines the walls. Here and there are blood sinuses filled with corpuscles especially in the region of the opening into the cloaca where the cells are lower, without secretory products and covered with an abundance of cilia.

The fact that these modifications occur simultaneously with those of the gonoducts strongly suggests that these organs in some way play a part in the reproductive process. They may function as uteri but obviously such conjectures are of very little value at the present time.

There is some reason to believe that the type of coelomoduct found in Chaetoderma is more like that of Chiton, and accordingly of a more primitive type than in the Neomeniina where they are provided with seminal receptacles, glands often of enormous development and spicula, in some cases, provided also with glandular appendages. It is interesting to note that in an immature

condition some of these more modified types present a simpler condition than at a later stage. In small specimens of the present species, about 14 mm. in length the various organs, connected with the reproductive system, hold the relations described above but they are far from being functional. The gonad, for example, is clearly paired throughout its entire length and the epithelium shows the merest traces of reproductive activity. The folds of germinal epithelium, that form a most characteristic feature of the adult organ, are commencing to appear on the latero-ventral surface of the gland, and there are slight evidences of a proliferation of cells on the inner wall of each gland. The dorsal aorta or sinus is of unusual size and in some places separates the two halves of the gonad completely, especially in front of the heart, where they are distant from each other by an interval equal to one third the diameter of the body. Thus widely separated they open into the pericardium, which, as in the adult, is of large size (Plate 15, fig. 9). The heart likewise is typical. The ducts leading to the exterior are of essentially the same calibre throughout; the seminal receptacle terminates anteriorly in a relatively long flagellum-like process; the spicule sheaths have developed though there are no traces of the organic basis of the spicules themselves as in decalcified specimens of larger size; and the vesicles opening into the cloaca are both present though their outlets are relatively large. Above all there are no signs of glandular activity. As noted on page 169 if these ducts are in part excretory this phase of activity should appear long before sexual maturity and its absence indicates that these tubes are merely for carrying off sex products.

In this species the sheath surrounding the nerve bundles is of unusual density or at all events stains with uncommon intensity in haematoxylin, so that branches not over 0.002 mm. have been followed. Owing to this fact more than usual care has been taken to determine the distribution of the more important trunks.

The brain, holding the customary position, dorsal to the pharynx, is of medium size and very clearly bilobed. From its anterior half the usual three pairs of nerves arise and at their origin each is connected with two ganglia, one very minute in size. These fibres extend laterally and anteriorly and after branching several times connect with ganglionic masses about the bases of the cirri.

A pair of very small nerves spring from the middle section of the brain close to the junction of its lateral and ventral surfaces. Each of these proceeds laterally and ventrally, and coming in contact with the sides of the pharynx branches and becomes lost among the numerous muscle fibres.

From the posterior half of the brain the lateral, pedal and labio-buccal connectives take their rise from independent, distinct roots (Plate 13, fig. 1). In side view the first two appear to be relatively short but in reality they extend laterally for a considerable distance at the same time bending ventrally to join the corresponding ganglia. All are practically devoid of ganglion cells. At the junction of each lateral connective with the ganglion there is a well-defined enlargement which anteriorly gives rise to a strong fibre passing forward closely applied to the somatic musculature. In the neighborhood of the atrium it branches repeatedly and the resulting fibres connect in some cases, at least, with the ganglia in the neighborhood of the cirri. At the union of this cord and the lateral ganglion another nerve appears which likewise rests against the body wall, and after passing forward and downward becomes lost to sight after branching a few times. This same anterior enlargement develops one or two very small laterally directed nerves which soon become indistinguishable among the somatic muscle fibres.

The lateral and pedal cords traverse the body holding the usual positions. Throughout their entire extent pedal commissures exist and approximately the same number of connectives unite the pedal and lateral ganglia. In the front end of the body, where the connectives are unusually distinct, they are often found to be united by commissures and accordingly lack the regular arrangement sometimes seen in figures of other species. As seen (Plate 13, fig. 1) the anterior connective gives off a branch that passes forward and seemingly unites with the ganglionic rod of cells attached to the base of the outer atrial ridge. This appears also to be the destination of another nerve originating from the front end of each pedal ganglion.

The labio-buccal ganglia are ellipsoidal bodies resting on the dorsal surface of the ventral salivary glands a short distance behind their outlet into the pharynx. From the anterior surface of each a strong nerve arises and in the usually contracted state of preserved material is considerably twisted before it expands and breaks up into three strong branches. Of these the more dorsal one is the buccal connective attached to the brain. The one immediately ventral to it extends anteriorly, slightly imbedded in the pharyngeal musculature until it arrives at the great dorsal fold. Here it bends sharply inward and deeply imbedded in the muscle bands crosses the pharynx to unite with its fellow giving off one or two delicate fibres on the way. A second dorsal commissure is formed by two relatively small nerves each of which springs from the anterior face of the labio-buccal ganglion. These, in closer proximity to the mid line than the

others for most of their course, become united above the pharynx slightly behind the dorsal pharyngeal fold.

At the junction of the labio-buccal connective and anterior dorsal commissure a third nerve arises probably to be considered the subradular connective. A short distance distal to its origin it originates two, sometimes three, small nerves which may be traced deep into the pharyngeal musculature in the neighborhood of the radula. Still farther outward a small ganglion is attached to it by a small stalk and between these two bodies the main fibre continues to complete the commissure.

In the posterior part of the body the pedal ganglia decrease rapidly in size, and become lost to view without being directly connected with the lateral cords. In this region the last four or five commissures are more than usually crowded together. The last three connectives on each side become united before entering the posterior end of the lateral ganglia, which here break up into four strong branches that pass backward, and after dividing repeatedly become lost in the walls of the cloaca and body including the posterior elongation. At the point where these nerves arise the lateral cords are joined by means of the customary suprarectal commissure.

Strophomenia scandens, sp nov.

Three specimens of this species were taken attached to a colony of *Acanthogorgia armata* dredged in the vicinity of Bird Island (Sta. 4156) at a depth of 286–568 fath. where the bottom was white mud and foraminiferous rock and the temperature was 45.8 F. The bodies of these animals were wrapped about the stems of the corals as shown (Plate 2, fig. 1), but none of the polyps in their immediate vicinity exhibited a shrunken appearance as though these molluscs had been indulging their appetites as in the case of Drepanomenia. The contents of the alimentary canal consisted only of a small amount of a finely granular substance.

The largest specimen measured 39 mm. in length and 2.1 mm. in diameter; the smallest was 32 mm. long with a thickness of 1.6 mm. The two ends of the body are similar in appearance, the posterior being slightly more slender and pointed (Plate 2, fig. 1). In cross section the body is in general nearly circular, but in both of the specimens at hand the ventral surface is slightly flattened. The atrial opening is an elongated slit surrounded by rounded lips, behind which the ventral furrow commences and posteriorly is continuous with the cloacal opening also subterminal in position.

The anterior portion of the ventral furrow forms a relatively deep depression (Plate 12, fig. 1) with corrugated walls, the opening of the anterior pedal gland. The gland itself occupies most of the visceral cavity in front of the forward end of the foot (Plate 16, figs. 1, 4). Its cells are of large size relatively, and are charged with a darkly staining secretion that makes its way by slender ducts to the ventral furrow, where each terminates in an intercellular opening. The secretion appears to be viscous, and in one of the specimens carefully dislodged it extended backward for a distance of 22 mm. as a narrow band.

The cuticle enclosing the body is about 0.2 mm. in thickness and as Plate 16, shows this measurement is very uniform save in the immediate neighborhood of the ventral furrow. Imbedded in its substance are, roughly speaking, six to eight layers of spicules, those from the back and sides of the animal being represented (Plate 37, fig. 17). Among these is a much smaller number of radially directed spines that become more minute and more abundant in the neighborhood of the foot.

The hypodermal layer is remarkably sharply defined, and not including the spicule forming elements and those connected with the papillae, consists of cells about twice as high as broad with greatly vacuolated protoplasm and well-defined nuclei occupying a more or less central position. Occasionally more slender cells are encountered but these may in reality belong to the papillae.

The development of the spicule is essentially the same as in *P. hawaiiensis* (page 28) both as regards the number and arrangement of the operating cells which also retain their connection with the spine as long as it remains in the cuticle.

As is shown (Plate 32, fig. 3) the papillae are numerous and closely crowded together at the surface. The expanded portion contains not far from twenty nuclei and the stalk from 2–5; otherwise there are no especial features of importance.

The foot arises in the extreme anterior end of the pedal furrow as a well-defined median ridge whose bounding cells are apparently covered with small cilia; but these are usually obscured by the huge cilia of the cells situated laterally. In the anterior portions of the ventral furrow the secretion from the anterior gland passes through intercellular openings at all points; more posteriorly it passes through the foot and the epithelium in immediate contact with it. The secretion of the anterior pedal gland when treated with Delafield's haematoxylin contains one substance which stains almost black and another of light blue tint. These appear to be two distinct secretions, for the dark sub-

stance escapes high up on the sides of the ventral furrow while the light blue product passes out more ventrally.

Behind the opening of the anterior pedal gland each side of the foot is accompanied by a longitudinal fold, which persists to near the hinder end of the animal when the lateral ridges, decreasing in size, pass into the general hypodermal covering of the body and are covered in large measure by the cuticle in which small spicules may be formed.

The atrial opening leads into a well-defined cavity (Plate 12, fig. 1) whose walls are provided with organs not unlike those in *P. hawaiiensis* for example. The outer sensory prominence and the outer and inner ciliated ridges are not so elevated, but the last two are composed of the same type of ciliated cells. At certain points the outer sensory ridge surmounts groups of ganglion cells from which fibres may occasionally be traced into close proximity to nerves that innervate the cirri. Along the median dorsal line another well-defined elevation is present between the two limbs of the inner ridge, but its cells are like those of the ordinary buccal epithelium and are probably not highly sensory.

In cross section the pharynx is roughly semilunar in shape, appearing relatively narrow when viewed from the side, but with a diameter of one fourth that of the body when seen from the dorsal or ventral surface. In front of the opening of the anterior pedal gland its cells are relatively high and slender, finely granular and contain more or less spindle-shaped nuclei placed at different levels. Behind this point the lining retains the same general character, but is developed into numerous and relatively low transverse folds supported by a small amount of connective tissue. Slightly in front of the labio-buccal ganglia the ridges become higher, the underlying connective tissue more abundant and among the cells of the usual type are a few others of more slender appearance with darkly staining elongated nuclei. It is possible that these elements are sensory in function, but owing to the large quantity of muscle and connective tissue in the neighborhood no special nerve supply has been distinguished.

Beyond these supposed sensory ridges the digestive tract bends abruptly upon itself and coursing upward and forward unites with the stomach-intestine (Plate 12, fig. 1). There is reason to suppose that this section between the labio-buccal ganglia and the gut represents the oesophagus, but with the exception that its epithelial lining consists of more spongy cells not produced into folds there is little to distinguish it as such.

The relations of the paired ventral salivary glands (Plate 6, fig. 6) are somewhat peculiar and except in very well-preserved material are difficult to determine,

a fact that may be responsible for some of the remarkable relations of these glands as described in some other members of the genus and in Rhopalomenia. In the present species these organs are placed side by side beneath the intestine and extend backward from their outlet for a distance equal to at least four times the diameter of the body. Anteriorly they diverge and enter the pharyngeal wall almost directly above the labio-buccal ganglia. Imbedded in muscle and connective-tissue fibres and some of the outlying pharyngeal glands, each canal now bends sharply upon itself (in two individuals) and becoming much more slender courses downward and somewhat backward to enter the pharynx on its ventral side. From the bend to a point close to their outlet these ducts are not only relatively slender but their lumen is of very small size and save in excellently preserved material, as in one of the specimens, is scarcely to be distinguished from the surrounding tissue. They are also composed of remarkably delicate material for in one specimen in which the organs are in a fairly good state of preservation this section of the gland has macerated and disappeared completely, leaving only the short and firmer outlets into the pharynx and the free main part of the gland.

On the ventral side of the pharynx the glandular portion of each of these organs ceases abruptly and becomes continuous with a canal of somewhat larger calibre composed of small cubical cells, that proceeds almost directly inward and opens ventrally into the pharynx close to the mid line. This terminal section of the salivary glands is a conspicuous object in sections, but its connection with the adjoining glandular part may be readily overlooked in which case the terminal section appears to be a short diverticulum of the ventral wall of the pharynx while the gland proper seems to unite with the pharynx near the dorsal side.

In the present species there is in addition to the various divisions of the salivary glands a median diverticulum whose relation to the digestive tract and buccal commissure support the belief that it is a rudimentary radula. The ventral wall of the pharynx forms a shallow pocket and the salivary ducts open into the bottom of this at each side. Exactly in the mid line and immediately above this pouch there is a small posteriorly directed diverticulum of the ventral wall of the pharynx and in two examples the buccal commissure passes dorsal to it (Plate 6, fig. 6), the relations being the same as in the radula of *P. hawaiiensis* for example. Its epithelial lining consists of low cells composed of highly vacuolated cytoplasm in which the nuclei hold a basal position, but there is no sign whatever of teeth.

Correlated with the posterior attachment of the pharynx is the excessive development of the anterior coecum (Plate 12, fig. 1), that extends forward to the hinder limits of the atrial cavity. In one specimen its walls are lined throughout with pyriform digestive cells, whose clear basal portion holds a small compact nucleus while the vacuolated distal part contains numerous granules characteristic of this type of cell. In another individual treated in precisely the same way the granular portion of the cells was absent as was the case in other parts of the digestive tract. As was noted in the case of *P. hawaiiensis* this appears to be the normal method of ridding the cells of their secretion. In the hinder portions of the coecum gut pouches appear and becoming more fully developed a short distance more posteriorly they continue with much regularity to the region of the heart where they abruptly disappear. Beneath the anterior end of the pericardium the intestine continues as a tube of relatively large calibre, but at the posterior end it rapidly narrows down to open into the cloaca (see Plate 12).

As is represented (Plate 13, fig. 2, and Plate 16), the pericardium of this species is of considerable size and contains in addition to the heart a number of mature ova. Histologically the differentiation of auricle and ventricle is not clearly marked and save for a constriction there is nothing to distinguish these two divisions. The blood occupying the interstices between all the organs in the posterior part of the body passes into the auricle by a wide opening and thence pours into the ventricle through an aperture not guarded by clearly defined valves. From the forward end of the heart the aorta takes its rise and with the usual position makes its way to the head after having supplied the gonad. The blood spaces at the anterior end of the body are very limited, more so in fact than is indicated in the figures which have omitted the intrinsic muscles of the digestive tract as well as retractors and protractors that attach to the body wall. However, the course that the blood takes in passing through the body proper differs in no essential particular from that of *P. hawaiiensis*.

The corpuscles are spindle shaped (Plate 36, fig. 12) and the small densely staining nucleus is superficially placed, in some cases being elevated above the surface of the slightly yellowish homogeneous cytoplasm.

In a preceding paper (Heath '04) attention has been called to the fact that in its more important details, especially in the relations of the labio-buccal system, the nervous system of this species shows a striking similarity to the Chitons and certain prosobranchs. The brain is relatively small and holds the usual position on the dorsal side of the pharynx behind the mouth cavity. As usual

three pairs of nerves arise from its anterior borders and are distributed to the various structures of the atrial and body walls. From its lateral margins the lateral, pedal, and labio-buccal connectives arise side by side. The lateral present the usual appearance as is also true of the pedal whose union with the pedal ganglia is marked by a well-developed enlargement. In nearly all cases if not invariably the labio-buccal ganglia of the Solenogastres are located near the openings of the paired ventral salivary glands when these exist, and since in the present species these are situated far back the connectives imbedded in the muscular pharyngeal wall are characterized by a relatively great length. The ganglia imbedded in the wall of the pharynx give rise to three commissures and to the subradular connectives. The dorsal and ventral buccal commissures are sufficiently indicated (Plate 6, fig. 6) to require no farther comment. In one specimen, possibly both, a well-developed ganglionic enlargement occurs on the ventral commissure and may correspond to the buccal ganglion, the other larger ganglion with which it is in close proximity and from which the subradular system is connected representing the labial. From this last named nerve mass another commissure passes ventral to the alimentary canal and in its course gives rise to two nerves which pass backward for a short distance and then become lost in the tissues of the pharynx.

As has been noted a typical subradular system is present in *P. hawaiiensis*. In *Limifossor talpoideus* it holds the customary position, but ganglia are apparently entirely absent. In one specimen of *Strophomenia scandens* very small masses of ganglion cells seemingly represent the subradular ganglia of which no sign exists in the other specimen. In this species no well-defined subradular organ occurs hence the ganglia are perhaps in a state of degeneration.

Owing to the comparatively small size of the latero-pedal and pedal commissures they are not readily followed yet in certain places they have been traced in dissections and sections, so that so far as may be judged they exhibit no unusual features.

In the posterior part of the body the relations shown (Plate 13, fig. 2) exist. As there indicated the lateral and pedal ganglia are united by two strong connectives, and posteriorly give rise to several branches that pass backward and become lost in the somatic musculature. From the middle of the suprarectal commissure a nerve arises that has been traced to the base of the dorso-terminal sense organ. This last named structure (Plate 32, fig. 9) is protruded above the general level of the cuticle. As indicated the cells are slender, naked, and rest upon a small accumulation of what are probably ganglion cells. Muscle

fibres attaching to the base, are probably retractors, the pressure of the blood in the underlying sinus being responsible for the protrusion of the organ.

The hermaphrodite gland holds the usual position and anteriorly extends to a short distance behind the level of the union of the oesophagus and gut. In all the specimens the sex elements are fully formed, some of the large ova having been dehisced and carried into the pericardial cavity. Posteriorly the gland gradually decreases in size finally passing into two long slender canals that unite with the front end of the pericardium (Plate 13, fig. 2). This last named cavity communicates posteriorly with the coelomoducts that extend backward a short distance before proceeding forward. At first the epithelial lining of these canals consists of low cells similar to those bounding the pericardium, but these are soon replaced by others almost cubical in form supporting an abundance of long cilia that continue to the seminal receptacles. These latter organs consist of from fifteen to eighteen sacs attached by short ciliated stalks to the gonoduct. In every case they were completely filled with spermatozoa.

The section of the coelomoduct, extending backward from the seminal receptacles, is lined throughout with relatively high columnar cells filled with a darkly staining granular secretion. Immediately back of the seminal receptacles these are developed into several longitudinal folds that quickly disappear more posteriorly. Still farther backward the two ducts unite a short distance in front of their outlet and in this single canal the internal folds reappear and persist to the cloacal cavity.

Immediately ventral to the outer opening of the reproductive system is a short diverticulum of the anterior wall of the cloaca (Plate 13, fig. 2, dt). Its cells are cubical in form and essentially like those of the cloaca at this point, but there is no sign of spicules or any secretion that indicates its possible use.

Strophomenia ophidiana, sp. nov.

One specimen of this species (Plate 1, fig. 2), attached to an alcyonarian coral, *Acanthogorgia angustiflora*, was taken off the southern end of Honshu Island, Japan (Sta. 3755) in water 52–77 fath. in depth. It measured 43 mm. in length and 2.5 mm. through the thickest part of the body. The color is creamy white shading to very light brown in the neighborhood of the head. A well-defined dorsal sense organ is present of the usual type.

The cuticle is relatively thick, measuring on an average 0.19 mm., and rests upon a thin hypodermal layer whose constituents present no especially note-

worthy features. The papillae are fairly numerous, especially ventrally where they project somewhat above the external surface of the body. Their shape and general character are represented in Plate 33, fig. 9. Small yellowish granules are scattered throughout the cuticle, but of their origin or function it is impossible to make any definite statements. The spines are shown (Plate 36, fig. 17).

The sensory atrium is exceptionally small (Plate 8, fig. 5) and the two outer ridges appear to be lacking altogether. The inner ridge, on the other hand, is clearly developed and typically placed but is of limited extent. The cirri in this genus are united as usual in groups of 2–5 and are composed of the customary cubical pigmented cells. Posteriorly the atrium opens into the buccal-pharyngeal tube, a long slender structure of about the same calibre throughout. Its lining is composed of slender epithelial cells produced into longitudinal folds especially in the anterior half. External to the epithelium is a well-developed layer of circular muscles and in contact with this a sheet of longitudinal fibres which become more abundant in the neighborhood of the stomach-intestine. In its anterior fourth this section of the digestive tract is attached to a considerable number of fibres which extend more or less radially to the body wall. Posterior to this region gland cells, arranged in small pear-shaped groups, are imbedded in the longitudinal muscle fibres and by intercellular canals open into the gut. The beautifully regular arrangement of these organs is shown (Plate 17, fig. 13).

Ordinarily the stomach-intestine connects with the posterior end of the pharynx or oesophagus, but in the present species such is not the case, for this junction is considerably in front of the ventral salivary glands which are appendages of the pharynx. However the ventral wall of the gut from the dorsal intestinal coecum to the openings of the salivary ducts and for an equal distance posteriorly is clearly pharyngeal in character, lacking the hepatic cells but possessing the characteristic muscle layers.

The ventral salivary glands are relatively long tubular structures penetrated eccentrically by a thin epithelial tube through which the outlying glandular cells open. Close to the outlet into the pharynx this glandular portion disappears, and the delicate duct makes its way through the ventral side of the pharynx to open into a small *cul de sac*.

No radula is present.

The extent and relations of the anterior intestinal coecum are well represented (Plate 8, fig. 5) and the intestine conforms so closely to the usual type that

it demands no description. Posteriorly the gut narrows rapidly, becomes somewhat rectangular in cross section as it passes between the limbs of the shell gland, and shortly before its outlet in the cloaca develops moderately high folds.

The pericardial cavity is of very large size (Plate 18, figs. 2, 3), and the contained heart is of the usual greatly elongated type. There are no distinct signs of a division into auricle and ventricle though a valve-like flap near its anterior end may indicate such or possibly the commencement of the aorta, which for a considerable distance is of as great diameter as the heart itself and even in the head region continues of large calibre (Plate 18, fig. 1). Its relations to the gonad and visceral cavity are similar to what occurs in *S. triangularis*. In the posterior part of the body the channels are more than usually ill defined, but the course of the blood is essentially the same as in the other species of the genus. The corpuscles possess the characteristic elliptical or pointed ovate form, and are accompanied by a relatively large number of leucocytes.

The gonad is fully developed, of relatively large size and the sex products are arranged in the customary fashion. Throughout its entire extent, but especially in the posterior half of the animal, the normal reproductive elements are associated with large masses of eggs in all stages of degeneration. This may be due to *post mortem* changes, but the sharply defined character of the various stages of the spermatozoa, ova, blood corpuscles, and other cellular elements in various parts of the body argues against such a view. In some species of Chitons (*e. g. Ischnochiton magdalenensis*) a considerable number of ova do not pass to the exterior during the egg-laying process, but undergo disintegration and are absorbed. Appearances indicate that this is the state of affairs in the present species, and the almost empty condition of the seminal receptacles further indicates that the breeding season has passed.

The ducts leading from the pericardial cavity are relatively slender though they enlarge somewhat before entering the shell gland, and as the cells change from a cubical to a columnar form they become increasingly glandular. An unusually large number of seminal vesicles are present, twenty-three occurring on the side of the body represented (Plate 9, fig. 1). In these the distal, usually vesicular portion is exceptionally small (Plate 18, fig. 4) but the diameter may be somewhat increased when the organs are filled with sperms. These bodies are attached not only to the forward end of the shell gland but several of them open into the dorsal section of the gonoduct. The component cells are columnar and show at various points faint signs of glandular activity. The shell gland on the other hand is highly glandular, more than usually irregular in outline and as

usual in the genus unites with its fellow of the opposite side so close to the cloaca that two openings appear to be present. The cells are all of columnar form and are of one type judging from the darkly staining granular secretion. As in other species of the genus a diverticulum of the cloacal wall is present ventral to the outlet of the shell gland, but there are no indications that it is of any especial significance.

In the other species of the genus Strophomenia described in the present paper there are from few to many diverticula extending outwardly from the cloacal wall, but they never reach the excessive development existing in this species. These are shown, somewhat diagrammatically (Plate 9, fig. 1). The cells are usually columnar and are filled with a finely granular substance which in various places is in the act of escaping into the cloacal cavity.

The brain, clearly bilobed, is located against the under side of the intestinal coecum at the level of the posterior border of the atrium (Plate 8, fig. 5). From it the usual three pairs of nerves originate, that after branching unite with ganglionic masses attached to the bases of the cirri or without such union pass to the body wall. The connectives to the lateral, pedal, and labio-buccal systems arise in the customary situations and the relations of the ganglia themselves, so far as they have been determined, are typical. Pedal commissures and latero-pedal connectives occur at frequent, though not perfectly regular, intervals and a corresponding number of unusually heavy nerves arise from the dorsal surface of the lateral ganglia. These have in several cases been followed close to the mid dorsal line but that they form commissures is not assured. They probably innervate the neighboring somatic musculature and hypodermis.

Posteriorly the pedal cords, united by commissures to the anterior cloacal wall, branch repeatedly in this last named locality and innervate the body and cloacal walls and some of the fibres become imbedded in the shell gland. The lateral cords at this same level likewise branch repeatedly and supply the same structures as the pedal, though more dorsally, and in addition give off a few small nerves that attach themselves to the pericardial wall. A very few branches from these last named nerves have been traced a short distance into the heart. The pedal and lateral cords are posteriorly united by one delicate branch; others may exist, but the nerves are not sufficiently differentiated from the surrounding tissue to permit of their being followed for any considerable distance. It is a peculiar fact that no trace of a dorsal posterior commissure uniting the lateral cords has been found to exist.

The labio-buccal connectives arise to the inside of the connectives leading

to the pedal ganglia, and at first resting upon the digestive tract and more posteriorly imbedded between the pharyngeal glands may be distinctly followed to well-defined ganglia in the neighborhood of the outlets of the ventral salivary glands. Owing to the fact that these ganglia are united by a large commissure dorsal to the ventral salivary glands, though ventral to the gut, they probably correspond to the labial ganglia. This commissure leads from the posterior ends of the nerve masses which more anteriorly are united by two more nerves ventral to the pharynx. One of these is a simple commissure like the more posterior one and like it is imbedded in muscles. The remaining one, imbedded in the same manner, is of much smaller size and soon unites with two small ganglia resting against the pharyngeal musculature somewhat ventral to the labial ganglia. These smaller ganglia are united also by a slender commissure. Comparing this system with what occurs in *P. hawaiiensis* it is probable that they form a subradular system which as in *Strophomenia scandens* has persisted, though the sense organ itself has almost if not completely disappeared. The labial ganglia are united also by a dorsal commissure leading out from their anterior surfaces. An unusual abnormality exists in this species in the form of two labio-buccal connectives on one side. One of these is incomplete since it is formed by a branching of the usual connective opposite the middle of the anterior pedal gland outlet. The more ventral branch, larger than the dorsal, makes its way to the underside of the pharynx and close to the mid line pursues a course to the neighborhood of the labial ganglia whereupon it bends outward at a sharp angle and unites with its fellow at the anterior end of the ganglion.

Strophomenia regularis, sp. nov.

This species is represented by the posterior end of one animal that, however, is so characteristic as to leave no doubt regarding its relationships. It was found in the bottom of the jar containing specimens of Dendronepthya (Spongodes) sp. and may therefore be considered to have come from the southern end of Honshu Island, Japan (Sta. 3717) at a depth of 75–100 fathoms. The length of the fragment is 9 mm. and the average diameter 1 mm. Its general outline is represented (Plate 26, fig. 8).

The coelenterate, with which this species was associated in the jar, was originally preserved in formalin that in decomposing had completely decalcified the fragment. It may be clearly seen (Plate 24, fig. 7), however, that for the most part the spicules are of the usual needle form and are accompanied by a relatively small number with truncated bases, all being imbedded in a cuticular

sheath 0.157 mm. in thickness on the side of the body. The hypodermis is very well preserved but presents no unusual features. Here and there, especially at the bases of some of the papillae, it contains cells, sometimes arranged in groups of three, staining darkly and apparently glandular though no trace of any outlet is evident. The spicules retain their connection with the matrix cells as long as they are imbedded in the cuticle (Plate 24, fig. 7). The enlarged portions of the papillae are relatively small, closely crowded together at the surface and are attached to the hypodermis by clearly defined stalks containing a few spindle-shaped nuclei.

A well-defined dorsal sense organ is present, apparently of the usual type though the oblique direction of the sections makes it somewhat difficult to determine its exact relations.

The foot is comparatively small, moderately ciliated, without any cavity, and extends to the cloaca. It is accompained by the usual glands whose appearance and relations are shown (Plate 24, figs. 9, 10).

The stomach-intestine presents the customary pouched appearance, and is lined with the ordinary glandular epithelium, changing to almost cubical ciliated elements beneath the gonad. Nettle cells of some coelenterate host are distinguishable in the small amount of material in the digestive tract. In the neighborhood of the front end of the pericardium the intestine narrows, becomes ciliated throughout, more or less rectangular in cross section then passes into a more tubular division which in its terminal section again expands and opens together with the gonoducts into the cloacal cavity.

As may be seen (Plate 24, figs. 9, 10) the pericardium in this species is of considerable size, and the presence of numerous muscle fibres passing from its walls to those of the body indicates that it probably undergoes considerable variation in this respect, probably while driving the sex products into the gonoducts. The heart, distended with blood, is a well-developed organ and comprises two divisions, an auricle and ventricle presumably. The walls of the auricle are somewhat more dense than those of the ventricle but otherwise their relations to the incurrent and excurrent blood streams are of the well-known type. The blood corpuscles are represented (Plate 24, fig. 14).

In its general relations the posterior portion of the nervous system resembles that of other species of the genus (Plate 26, fig. 8). The pedal cords, connected by numerous commissures, continue of about the same calibre until they reach the region of the cloaca. Here they enlarge very slightly, give rise to two or three strong connectives and as many smaller commissures, and then gradually

become smaller, disappearing after breaking up into a small number of branches that become lost among the somatic muscles. The lateral cords, on the other hand, enlarge as they approach the posterior end of the pericardium where they form a well-defined ganglion. From it connectives, of at least twice the diameter of those more anterior, pass to the pedal cords. The usual commissure passes dorsal to the gut; while posteriorly two or three nerves make their way into the somatic musculature, and one unites with a sharply defined ganglion from which branches arise whose subdivisions are distributed over the cloaca and the body wall of the same region. In this species the nerves destined to the dorsal sense organ are two in number. They arise, widely separated from each other, from the dorsal commissure, and passing along the dorsal side of the animal reach the base of the sense organ. In the present specimen one of the nerves for a considerable distance traverses the sinus entering the posterior end of the heart.

As is generally the case with the genus the halves of the gonad are relatively wide apart in the posterior part of the body, being separated by a correspondingly wide blood sinus, and more posteriorly they shade gradually into the pericardium. From this latter cavity the gonoducts arise as relatively wide tubes of fairly even calibre lined with cubical ciliated cells without any marked signs of glandular activity. At the union of the dorsal section of the gonoduct with the ventral part or shell gland a number of seminal receptacles are attached, twelve being present on the side of the body represented (Plate 26, fig. 8).

As may be seen these are of varying size and are attached by short stalks (Plate 24, fig. 10). In the present specimen developing ova are present in considerable numbers, and a few are free in the cavity of the gonad; on the other hand spermatozoa are of rare occurrence. However, in the dorsal section of the gonoduct adjacent to the receptacles, and in the receptacles themselves sperms are abundant without any definite arrangement or in some of the receptacles attached by their heads to the walls (Plate 24, fig. 13). Muscle fibres, attached at various points to the outer walls of these reservoirs and on the other hand to the body wall, pericardium or shell gland, probably cause the dilation of these organs, while a delicate cuticular sheath to which the lining epithelium is attached may be responsible in part for their contraction. The shell gland, from side view, is somewhat irregular in outline but in cross section is very symmetrical (Plate 24, fig. 9). Its walls are of only moderate thickness and at most levels the lumen is a narrow slit. Throughout five sixths of its extent the cells, high and columnar in form, are moderately filled with a finely granular

secretion that stains intensely and in this form makes its escape. In the posterior sixth the cells are of essentially the same form, but their contents stain a faint pink. As noted above the rectum opens with the halves of the shell gland into a shallow depression on the forward wall of the cloaca.

Strophomenia farcimen, sp. nov.

Two specimens of this species were collected off the southern end of Honshu Island, Japan (Sta. 3748), at a depth of 73–200 fathoms. One was attached to a colony of the alcyonarian, *Acanthogorgia angustiflora*; the other was likewise clinging to a mass of a species of Dendronepthya (Spongodes). The length of the type specimen (Plate 1, fig. 1) is 18 mm., width 2 mm. The color in formaldehyde is creamy white. A well-defined dorsal sense organ is present. From external view the outlet of the anterior pedal gland is no wider than the ventral furrow generally which is continuous with the cloaca.

The cuticle, approximately one tenth the thickness of the total body width, rests upon a hypodermal layer of unusual thinness (Plate 33, fig. 2), and is composed of minute elements most unfavorable for study. The papillae are of moderate size, and are attached to long fibrous stalks containing 3–5 nuclei and at the surface of the cuticle are closely crowded together. At the junction of the stalk and dilated portion as many as 5–9 nuclei may occur in a given section; the remainder of the dilation is filled with numerous small greenish yellow granules. The ordinary type of spicule, needle-like (Plate 17, fig. 17), forms 5–7 layers, while the second type, usually with more truncated base and more curved acute tip, is located more at right angles to the hypodermal layer. It is worthy of note that the somatic musculature is exceptionally thin, the plump rounded appearance of the specimens in hand being due to the firm consistency of the cuticle.

The anterior pedal gland, holding a position from the atrium to the hinder border of the crypt-like outlet, is composed of lobules of small cells filled with a faintly or darkly staining secretion according to the stage of its development. The ductules make their way through intercellular spaces into the forward end of the pedal furrow, which is comparatively small and in cross section usually presents the appearance represented (Plate 17, fig. 11). Near its anterior border the foot originates as a high slender fold and extends to the cloaca. Unlike most species the cells of the posterior pedal gland open not only into the bottom of the pedal furrow but also between the cells of the foot, which is provided also with considerable numbers of gland cells.

In several important particulars the digestive canal of the present species resembles that of other members of Strophomenia. The atrial ridges are, as usual, two in number and enclose the cirrose area; the more external is horse-shoe-shaped and is composed of slender columnar, ciliated cells which contain spindle-shaped nuclei and a very small amount of pigment. External to the outer one is a low ridge of somewhat similar cells which, as in *P. hawaiiensis*, rests upon a rod-like mass of ganglion cells. The cirrose area is rather small in extent (Plate 7, fig. 1), and the finger-like processes, arising separately from the bounding wall, are composed of the usual pigmented cells, internally limiting an exceedingly slender cavity penetrated basally at least by delicate strands of connective tissue and probably nerve fibres. The opening from this sensory atrium into the succeeding portion of the gut is bounded by a ring-like fold, which is probably capable of protrusion to the exterior as it is supplied with numerous muscle fibres. Beyond this proboscis the pharynx pursues its way for a distance almost as great as in *Strophomenia scandens*. In the early part of its course its lumen is small, owing to the heavy folds developed in its walls (Plate 17, fig. 11), but more posteriorly, and especially in the neighborhood of the radula, it becomes a canal of greater size. As far posteriorly as the forward end of the radula its walls are supplied with numerous glands, consisting of many small, pyriform cells, united into bundles by means of connective-tissue fibres, opening probably by separate intercellular crevices into the pharyngeal cavity. In the neighborhood of the opening of the radula sac the canal, probably to be considered as the œsophagus, again narrows, and its walls, composed of high columnar cells, become developed into high ridges extending nearly to the centre of the lumen.

The radula is well developed and typically located, but the teeth composing it are thin and delicate, since the sections display few traces of displacement owing to the sectioning process. In cross sections it is very difficult to determine the exact number of teeth, but there appear to be fifteen rows of from 24–28 in each row each having the form represented in (Plate 34, fig. 15). The basement membrane is continuous across the mid line, but the bases of the teeth are so fused that at first sight the radula appears to be of the distichous type.

The dorsal intestinal cœcum is of great length, as in *Strophomenia scandens*, and is filled, as is the gut, by vast numbers of what appear to be partially digested nematocysts. In a few places ova, probably rasped from the tissues of the host, occur within the food mass. The cells lining the intestinal tract are highly vacuolated and difficult to clearly define. The gut pouches likewise lack the

usual regularity of other Neomeniina and frequently present a more than usually complicated appearance in cross section. In the posterior end of the body the gut narrows, and becoming triangular (Plate 17, figs. 14, 15), passes between the cloacal passage and finally becoming reduced to a small, apparently ciliated canal it opens together with the coelomoducts into a depression in the anterior cloacal wall.

The ventral salivary glands are long tubular bodies opening into the pharyngeal cavity on each side of the radula (Plate 17, fig. 16). In their proximal portions they are delicate thin walled canals lacking any signs of glandular activity; more distally these tubes continue in an unchanged condition, but each becomes enveloped excentrically in a mass of gland cells. These elements are pyriform, filled with a finely granular, lavender colored secretion, which makes its way into the duct by means of ductules opening through intercellular canals.

The heart is of relatively great length, and, with the exception of a few irregular outpouchings near its posterior extremity, is tubular throughout. There is thus no clearly defined auricle and ventricle nor line of demarcation between it and the aorta. This last named vessel is of exceptionally large calibre, but its relation to the gonad and its route into the perivisceral sinus are normal. This last named space, owing to the unusually small number of muscle bundles binding the gut to the body wall, is of large size, but the course of the included blood into the median pedal sinus and posteriorly into the heart are typical. The blood corpuscles are thin, plate-like bodies, usually like a spear-head in shape, and rather closely resemble those of *Strophomenia scandens*.

The nervous system, as it is not especially favorable for study, has been studied in a general way only, but sufficiently to indicate that it is not essentially different in this regard from other species of the genus.

The gonad extends as far forward as the radula where its halves are widely separated by the large aorta, but more posteriorly they come in contact beneath this vessel. The animals are dioecious and the sex cells are developed normally. The coelomoducts take their origin from the extreme posterior border of the pericardium (Plate 11, fig. 4) in the form of comparatively thin walled tubes in which the lining epithelium is low and seemingly ciliated. Extending anteriorly this dorsal division of the cloacal passage unites with the ventral section about the level of the anterior end of the pericardial cavity. At the intersection of these two divisions upwards of nineteen seminal receptacles are attached, in appearance and arrangement closely resembling those in *Strophomenia scandens*.

Each consists of a more or less pyriform sac with walls of median thickness to which the spermatozoa are attached in large numbers. In the ventral section, or shell gland, the walls are not so thick as is usual with the majority of Neomeniina and the central cavity is of greater size (Plate 17, fig. 15). The component cells are long and contain multitudes of spherical granules staining intensely with haematoxylin. Posteriorly the halves of these glands do not unite with each other or at least not to any marked extent but open separately, though close together (Plate 17, fig. 12), into a shallow depression in the anterior cloacal wall into which the rectum opens also. Immediately ventral to this depression there is an outpushing of the wall of the cloaca, that thus holds the same position as the diverticulum in *Strophomenia scandens*, but it is much more shallow and not so completely closed. The walls of the cloaca lack any folds of definite arrangement, but at three or four points bear slender finger-like outpouchings though without any special modifications to indicate their possible function.

Strophomenia spinosa, sp. nov.

Five specimens of this species were taken in southern Japan in the neighborhood of Misaki (4 from Sta. 4935–6 and 1 from Sta. 3748) at a depth of 73–200 faths., all were attached to the alcyonarian coral, *Acanthogorgia japonica*. Externally the appearance of these animals differs to a greater degree than in any other species described in the present paper. As may be seen (Plate 1, fig. 3) some (the larger) specimens are almost smooth, while others present such a highly spinose appearance that at the outset they were supposed to be distinct species.[1] Here and there sections show that some of the great spines ordinarily protruding almost at a right angle above the cuticle have been withdrawn so that their bases invade the territory of the somatic musculature (Plate 33, fig. 7); and it appears probable that this species is able to protrude or withdraw these spines and possibly adapt itself to a shifting habitat as *Echinomenia coralliophila* is known to do. The length of the body is approximately 28 mm. with an average diameter of 1 mm. Both ends of the body are similar, the anterior being distinguished usually by its slightly greater thickness. The color is grayish white.

The cuticle, 0.1 mm. in thickness (Plate 33, fig. 7), is in reality rather scant

[1] It is possible that these differences in external appearances are of specific value, and that we are dealing with two distinct forms. Plate 34, figs. 8, 9, 10, show differences in the radulae, and in the "smooth," large form there are thirty-one seminal receptacles while there are twelve in the smaller, spiny type. Nierstrasz ('02), however, claims that these last named organs vary considerably in number in the same species. Additional material is necessary to settle the question.

in amount, forming as it does scarcely more than a thin sheath about the innumerable spicules imbedded in it. The latter structures are of two varieties shown (Plate 36, fig. 16), the larger being directed radially.

The hypodermis, comparatively thin and not especially favorable for study, comprises so far as determined the usual types of cells. Those responsible for the development of the needle-shaped spine retain their attachment with it so long as the spicule remains in the cuticle. The formation of the spines with truncated base has not been followed, but in later stages each rests upon a small knob, probably the remains of a matrix cell, and as noted previously may be withdrawn deep into the somatic musculature. This appears to be a normal process for as noted in a previous paragraph some specimens are smoother externally than others; but the mechanism by which this is effected is by no means clear since in a few cases only do muscles attach to the base of the spine. The papillae are few in number.

The anterior pedal gland is a moderately developed organ extending from the level of the brain to the posterior border of its outlet into the pedal furrow. The cells are of the usual pyriform type and contain a secretion staining inky black with haematoxylin. The outlet is a simple sac-like indentation (Plate 8, fig. 2, and Plate 11, fig. 2), highly ciliated, with the foot springing as a well-developed fold from its dorsal wall. The cells of the posterior pedal gland are unusually numerous anteriorly and save that they are of a somewhat smaller size are not to be distinguished from those of the anterior pedal gland with which they are continuous. Posteriorly the furrow is continuous with the cloacal chamber.

The opening of the sensory atrium, subterminal in position, is comparatively wide, and as may be seen (Plate 11, fig. 2 and Plate 8, fig. 2), the atrium itself is imperfectly separated from the succeeding section of the gut. As usual three pairs of sensory ridges are present, the two bounding the cirrose area being well defined while the remaining more exterior one is only faintly outlined. The first two mentioned are comparatively low, not penetrated by blood sinuses, but by connective tissue and muscle fibres and a very few nerve fibres from neighboring ganglia. The cirri are slender, compact bodies united in groups of 3–6.

The mouth, a relatively wide opening, leads into a tube of great length, but of much the same size and appearance throughout its course. Its epithelial lining is usually fashioned into low longitudinal folds and rests upon a circular muscle layer of moderate thickness external to which are a few longitudinal bands

and radial fibres attaching to the body wall. As may be seen in Plate 8, fig. 2, numerous pyriform masses of cells attach to the pharynx throughout its entire extent and pour the secretion into the digestive canal through numerous intercellular openings. The ventral salivary glands are long tubular bodies with a very slender duct through which the attached gland cells pour their secretion. Their openings into the pharynx are exceedingly narrow but occur in normal position at the sides of the radula (Plate 17, fig. 4). The long dorsal coecum, the fairly regularly pouched mid gut, and the relations of the rectum are all typical.

The radula is evidently in a highly degenerate condition, and differs considerably in different specimens. In the individual represented (Plate 34, fig. 8), it is exceedingly minute and appears to be clearly monoserial. In Plate 34, figs. 8, 9, it is considerably larger, biserial and the teeth next the median line are noticeably smaller than the others. Judging from the specimen possessing the larger radula (Plate 34, fig. 10), there are eight transverse rows.

The heart is the usual long, tubular organ represented in cross section (Plate 17, fig. 5) and the other features of the circulatory system are so typical of the genus that they require no further comment. The corpuscles are very similar in outline to the spines of *Limifossor talpoideus*, being pointed ovate in shape. The nucleus is superficially placed, and may protrude somewhat beyond the general level of the cell.

The gonad in its position and the development of the sex products is normal; and its connection with the pericardium is made, as usual with this genus, by means of canals of unusually large calibre (Plate 9, fig. 4). Posteriorly the pericardial wall is produced into two pouches, separated by the sinus entering the heart, which are continuous with the coelomoducts. The lateral surfaces of these pouches and the pericardial wall for some distance in front of them, and especially the coelomoducts themselves as far as the seminal receptacles, are ciliated, the coat being especially heavy in these last named tubes. Roughly the height of the cells of these regions is proportional to the thickness of the ciliated coat, ranging from flat or cubical elements in the pericardium to those in the neighborhood of the seminal receptacles where the ratio of height to thickness is about 3: 1. The larger cells are developed into a few longitudinal folds and are endowed with a considerable degree of glandular activity.

The ventral section of the coelomoduct, or shell gland, is joined somewhat behind its anterior end by the dorsal section, and the blind sac thus developed serves for the attachment of a greater number of seminal receptacles than in any

other species described in the present paper. On the side represented (Plate 9, fig. 4), there are thirty-one and as may be seen these are of various sizes, ranging in diameter from 0.2 mm. to one fourth this size. On the other hand it is to be noted that another specimen from the same alcyonarian colony has but twelve receptacles (Plate 12, fig. 3). The cells composing these organs are unusually large and in many situations are greatly vacuolated. This latter peculiarity, however, may be due to the fixing fluid since at all points where spermatozoa are attached to the walls the cells are more dense though of the same height as the others. The stalks connecting the receptacles are comparatively short, lined with low cubical cells and usually open separately into the coelomoduct (Plate 17, fig. 5).

The shell gland is nowise peculiar except that it is of somewhat greater diameter than usual and more irregular in outline. Its cells are columnar and are partially filled with a darkly staining secretion that has escaped into the lumen in considerable quantities. It may be added that in specimens of this type ova occur in the pericardial cavity and the breeding season is therefore at its height. As usual the halves of the shell gland are not clearly united, but with the rectum open together into the cloaca.

Strophomenia triangularis, sp. nov.

Five specimens of this species were taken off the southern end of Honshu Island, Japan, two from Station 3716, two from Station 4935 and one from Station 4936 at depths of 65–125, 103 and 103 faths. respectively. The length of all is approximately 12 mm. with a width of 1.6 mm. The body is flattened ventrally, and the presence of a low broad keel extending along the dorsal side of the body and terminating about 1 mm. from each extremity, gives the animal a triangular appearance in cross section. Every specimen is coiled in a close spiral (Plate 1, fig. 5) around the stem of an alcyonarian coral, Calicogorgia sp.

The color of preserved material is a dull grayish yellow. The opening into the atrium is subterminal, and is clearly separated from the ventral furrow. The foot, a single fold, extends from the hinder wall of the anterior pedal gland outlet to the cloaca. A dorso-terminal sense organ is present. The cuticle on the back and dorso-lateral surfaces measures 0.108 mm. in depth to twice this thickness on the ventral surface. In decalcified material the papillae extend more or less above the surface of the cuticle (Plate 33, fig. 1), but in a natural state these are so surrounded or overlaid by spicules that they are usually invisible in surface view. The outer enlarged portion of each papilla is relatively

small though considerably larger than in the case of others, apparently younger and more deeply imbedded in the cuticle. In almost every case the 10–15 cells comprising it are contracted into a mass in contact with the stalk that is very slender and rarely contains more than two nuclei.

The sensory atrium holds the usual position (Plate 36, fig. 6) and contains the characteristic elements, of which the external ridge entirely surrounds the atrial cavity save posteriorly where it joins the internal ridge. This last named organ is likewise continuous across the mid line as a low inconspicuous elevation which more posteriorly becomes developed into a very sharply defined structure uniting with the outer ridge. The included area is beset with slender cirri, united into groups of 3–5 and composed of small cubical cells containing the usual yellowish pigment. In many cases muscle fibres pass up into the central cavity of each cirrus, and nerve fibres from neighboring ganglia may be traced to the basal portion. The opening from the atrium into the next section of the digestive tract is on the posterior atrial wall and leads into a relatively long pharyngeal tube developed internally into several longitudinal folds lined with a delicate cuticle and composed of slender columnar cells usually filled with some glandular secretion, especially in the section next to the atrium. In this same fourth groups of cells (shown against under surface of digestive tract, Plate 18, fig. 6) appear in each section attached to the outer surface of what is probably the buccal epithelium. Directly opposite the outlet of the anterior pedal gland these elements, are in large measure replaced by others, likewise in groups, and filled with a darkly staining granular secretion or more posteriorly where they are larger, with a highly vacuolated substance but little affected by haematoxylin. These glands extend backward to the radula or at the point where the ventral salivary glands open. These last named organs are tubular, at least 1.5 mm. long and 0.15 mm. in average diameter, and open into depressions on the pharyngeal wall on each side of the radula (Plate 18, fig. 9). A thin epithelial lining borders the lumen while the outer surface is in contact with gland cells, pyriform and filled with a secretion differing considerably in different specimens and parts of the same gland. At some points the cells are closely packed with a bluish or pinkish secretion or at others this material is collected into rounded particles, dark brownish yellow in color, surrounded by a vacuole of considerable size.

The radula, typically located, seemingly belongs to the distichous type, and yet is readily related to the polystichous form occurring in other genera if we assume that the bases of the once distinct teeth have secondarily fused.

From transverse sections it appears that there are fifteen rows of teeth whose general form is shown (Plate 34, fig. 4). They are thin and delicate, or at all events are not easily displaced in sectioning, and stain readily in haematoxylin.

As usual with this genus the anterior intestinal coecum is of great length and considerably in front of its union with the pharynx exhibits most of the essential characters of the stomach-intestine, possessing fairly regular outpouchings and an epithelial lining of the customary glandular type, but lacking the cubical ciliated cells beneath the gonad. The coecum and most of the succeeding portions of the gut contain nettle and germ cells extracted from the host. Opposite the seminal receptacles the intestine narrows, becoming gradually smaller until it opens into the cloaca (Plate 18, fig. 10). At the same time the dorsal ciliated epithelium gradually extends round the sides of the rectum, finally meeting in the mid ventral line shortly in front of the anal opening.

The pericardial cavity in this species is of very large size and the heart of unusual length. The posterior division, however, is unusually small and peculiar in being paired, save at its junction with the ventricle with which it communicates by a single small pore apparently furnished with a valve. The aorta, at its origin, is of the same calibre as the ventricle and occupies the entire though narrow space between the halves of the gonad. The branches, passing from it around the ventral and lateral surfaces of the gonad to unite with the visceral cavity, are likewise of large size and very distinct. More anteriorly these branches become much smaller and in the region of the head all but disappear in the present specimen. The course of the sinuses in the head, their union with the ventral sinus and the relation of the latter vessel with the heart are typical. The corpuscles are more than usually compact, but in their ellipsoidal form resemble those of other species of the genus.

The gonad extends as far forward as the radula and presents the usual features. Posteriorly it opens, in both specimens examined, by unusually large ducts into the pericardium, owing possibly to the fact that the time the animals were killed ova were present in considerable numbers in the pericardial cavity and along the cloacal passages. These canals, arising typically from the posterior end of the pericardium (Plate 9, fig. 3), average approximately 0.095 mm. in diameter and are lined with cubical and low columnar richly ciliated cells. Toward the median line of the body these elements are more glandular and the secretion may direct the course of the sperms.

The seminal receptacles, numbering 10–12, vary in size as may be seen (Plate 9, fig. 3), and possess unusually long stalks. Both vesicle and duct are

composed of cubical cells, those of the latter being twice the height of the others. In the receptacle spermatozoa are numerous and are attached by their heads to the wall.

The anterior half of each ventral section of the cloacal passage (the shell gland) is composed of cells of the appearance represented (Plate 18, fig. 8), filled with a distinctly granular, darkly staining secretion. In the remaining half the appearances are much the same save that the glandular material is of a pink or reddish color. The halves of the shell gland open into the cloaca by separate pores and a fold, distended with blood, separates in large measure these openings from that of the intestine.

The nervous system is typical in its general features. In the labio-buccal system two commissures unite the ganglia ventral to the pharynx; one of these bears a pair of small ganglia as in *Strophomenia scandens* (Plate 6, fig. 6). One commissure likewise passes dorsal to the pharynx. The relations of this system are essentially the same as in Plate 6, fig. 6, with the exception of the most posterior ventral commissure that appears to be lacking in the present species.

Lophomenia spiralis, sp. nov.

This species, represented by two specimens (Plate 2, fig. 4), was taken in the vicinity of Niihau Island (Sta. 4176) at a depth of 537–672 fath.; bottom, gray sand and foraminiferous mud; temp. 38.3 F. Both individuals were closely wrapped about the stalk of a hydroid colony (*Cryptolaria operculata* Nutting) and sections disclose the presence of nettle and other cells in the alimentary canal from which we may infer that these forms, like *Drepanomenia vampyrella*, prey upon the polyps.

Both specimens were of almost identically the same shape and size, measuring approximately 24 mm. in length and 1.5 mm. in average diameter. Each end of the body terminates in a fairly sharp point but as the mouth is subterminal and surrounded by well-developed lips it may readily be distinguished from the cloacal opening that extends a short distance on to the dorsal surface. The ventral furrow holds the usual position, being continuous with the cloaca posteriorly and in front terminating immediately behind the atrial opening. In one individual where the pharynx was slightly retracted this groove appeared to be directly continuous with the atrium but sections prove conclusively that such is not the case.

The opening of the pedal gland as usual occupies the anterior end of the ventral furrow. Its position, shape, and general appearance are accurately rep-

resented (Plate 6, fig. 5). The hypodermal cells bounding the cavity are higher and more slender than the usual type and are richly ciliated. All contain spindle-shaped nuclei and lightly staining cytoplasm. Immediately behind the outlet of the anterior pedal gland the foot arises and extends to the opening of the cloaca. At the outset it is well developed but gradually decreases in size posteriorly until near the cloaca when it enlarges to twice its average size. A short distance behind its front end the hypodermal cells lateral to the base cease to develop spines and assume the form of a ridge (Plate 19, fig. 3) that increasing slightly in size continues to the cloaca where each like the foot enlarges somewhat before disappearing. At all points the cavity of the foot is very small, never spacious enough to permit the entrance of blood corpuscles.

The relations of the anterior section of the digestive tract are shown (Plate 6, fig. 5). Here the pharynx is somewhat protruded, but it is evident that the structures borne on the buccal wall are not unlike those of the other Neomeniina hitherto described. Immediately within the lips the usual ciliated atrial ridge is present. However it is relatively short, its contained blood sinuses small and the component cells low and very slightly pigmented. This is also true of the inner elevation with the exception that in both specimens it is of somewhat greater height. The cirri of the included area are relatively slender and are usually attached separately to the buccal wall. Their cavities are of extremely small calibre and it is only in exceptional cases that the contained nerve fibre may be determined. Also their cell boundaries are indistinct, but otherwise these organs are not unlike those in *Proneomenia hawaiiensis*.

The pharynx consists of two distinct portions, the first a relatively slender tube leading from the mouth into the second enlarged section that opens in turn into the stomach-intestine. Throughout the epithelial lining consists of columnar cells, forming at first low longitudinal ridges that gradually increase in height attaining their maximum size at the opening into the stomach.

At the junction of the first and second sections the pharynx is produced into a much folded diverticulum that affords an outlet for the dorsal salivary gland (Plate 6, fig. 5). This last named organ is relatively very voluminous, larger in fact than in most species of Solenogastres hitherto described. With the exception of two narrow lateral areas held by the anterior pedal gland it occupies the dorsal surface of the digestive tract, and to a much less extent, the lateral borders between the brain and stomach-intestine. In the most favorable sections the component cells are clearly pyriform and are connected by a narrow duct filled with granules that leads to the pharynx. Some of the smaller cells

are fairly well filled with small particles which in the larger cells are applied to the cell membrane, the remaining contents consisting apparently in life of a fluid. In the majority of cases the nucleus is spherical, finely granular and contains a distinct nucleolus.

The position of the radula is shown in Plate 6, fig. 5, while a cross section of the radula tube is represented (Plate 34, fig. 1). From these it will be seen that this organ belongs to the distichous type and that there are about twenty rows of teeth. While the shape of each tooth is sufficiently shown in the figures it is worthy of note that in the radula tube the base of each tooth is connected by a narrow cuticular bridge. When the radula opens out into the pharynx each plate appears to split in half, at all events the exposed teeth in one specimen at least are fully three times farther apart than in the radula tube and they do not appear to be connected by a basal plate.

Immediately in front of the radula there is a pair of short diverticula of the pharyngeal wall which serve as outlets of the salivary secretion. The mass of the outlying gland comprises several divisions bounded by connective tissue and located chiefly at the sides of the pharynx. The cells themselves are pyriform, highly vacuolated and their ductules attach chiefly to the dorsal side of the main duct.

The stomach-intestine assumes its average diameter at once and gut pouches appear close to the anterior end. No forward coecum is present. The epithelial cells lining the tract at first form a flat surface but a short distance backward they become arranged in the form of longitudinal folds (Plate 19, fig. 3) that continue to the neighborhood of the accessory reproductive organs. In the latter region the diameter of the intestine decreases, its lining walls are smooth, and wedged in between the cloacal passage and the pericardium, it makes its way to the cloaca. The cells of the rectum are pear shaped with basally situated dense nuclei and the distal portions are swollen with a secretion that in the form of a darkly staining finely granular mass fills the lumen of the gut.

In this species the pericardium is long and the contained heart is relatively slender (Plate 8, fig. 6). The blood from the posterior part of the body enters the hinder extremity of the heart which here has the form of a very slender tube (Plate 19, fig. 9), attached to the dorsal wall of the pericardium. About midway in the pericardial cavity this canal enters another section, of four or five times greater diameter, that for a short distance hangs freely in the pericardium but more anteriorly unites with the pericardial wall and with gradually diminishing calibre holds this relation until it passes into the aorta. This latter vessel

supplies the gonad in the usual way and in the head region breaks up into a system of sinuses that become continuous with the blood spaces lying at the sides and beneath the intestine. In the region of the accessory reproductive organs the lacunae become very circumscribed, but so far as they have been traced they exhibit essentially the same relations as in *P. hawaiiensis*. The corpuscles of this species (Plate 36, fig. 14) exhibit no features worthy of note.

The paired gonad extends forward to a point some distance behind the junction of the pharynx and stomach-intestine. Posteriorly it ends abruptly slightly in front of the pericardium with which it is connected by two short ducts. The arrangement of ova and sperms are the same as in the foregoing species. From the posterior end of the pericardial cavity the coelomoducts arise and proceeding forward (Plate 8, fig. 6, and Plate 9, fig. 5) almost horizontally unite with the shell gland. In one specimen the first section of these tubes is of small diameter and ill defined, while in the other it is well developed and is filled with spermatozoa that also crowd the pericardium. In this same individual there is a circumscribed area including the extreme posterior tip of the pericardial cavity and the neighboring section of the coelomoduct where numbers of spermatozoa are attached to the epithelial lining. Beyond this point for some distance the duct continues of small calibre, with an epithelial lining composed chiefly of goblet-shaped cells charged with a clear secretion, and then suddenly terminates in a bulb-like enlargement that in turn unites with the seminal receptacle and the slime gland proper. At first the cells in this swollen division are of greater height and more slender than those adjacent, and attach vast numbers of spermatozoa, but more anteriorly sex cells are lacking and the epithelium consists of goblet-shaped elements like those just described save that they are of larger size. The same type of cell also occurs in the elongated seminal receptacle except at its distal end where the cells are lower, more compact and also attach large numbers of spermatozoa.

The ventral limbs of each coelomoduct extend backward from the point of attachment of the seminal receptacle to a point a short distance in front of the cloaca where they unite and communicate with the exterior by a single opening. The epithelial lining in this part of the duct is relatively very high and gives evidence of forming two distinct secretions. The cells in the anterior third of the canal are much vacuolated and contain a small amount of some faintly staining secretion. More posteriorly they gradually shade into more slender and elevated elements that, in the posterior half of the cloacal passage, contain numerous granules densely crowded in their distal portions. Such

cells are confined almost exclusively to the ventral and lateral walls. The dorsal side in both specimens consists entirely of cells whose entire substance, with the exception of a small basally placed nucleus imbedded in a scant amount of protoplasm, consists of a vacuolated homogeneous secretion staining like the muciparous cells of certain gastropods. It is possible that such a secretion is due to the transformation of products similar to those of the ventral granular cells, but there is no trustworthy evidence that such is the case.

On each side of the ventral furrow immediately in front of the cloacal opening are two indentations of the hypodermis each of which contains not less than fifty needle-shaped spicules that are clearly modifications of the spines produced in the adjacent territory. As is shown (Plate 19, fig. 5) they are directed inward toward the mid line and sections show that multitudes of muscle fibres attach to the diverticulum chiefly on its blind extremity. Among the more prominent of these is a transverse band, another extending outwardly and attaching to the body wall and, most prominent of all, numerous strands that pass in a postero-lateral direction and attach to the body wall slightly behind the level of the cloacal opening.

In its broader features the nervous system of this species corresponds closely to that of the other species described in this paper. The brain is of the ordinary bilobed type and is placed above the buccal cavity (Plate 6, fig. 5). From it six nerves arise that passing forward and downward probably innervate the buccal and body walls with the attendant sense organs. The relations of the pedal, lateral, and buccal connectives also conform to the usual type. The last named cord is exceedingly difficult to follow owing to its almost exact resemblance to the dense masses of muscle and connective tissue that accompany it, but with high magnification it may be traced to the elongated ganglia placed at the sides of the radula and a little below it. The commissure attaching to the posterior ends of the ganglia passes dorsal to the radula. No clearly defined subradular organ exists and no nerves or ganglia belonging to this system are present so far as it is possible to judge from the material in hand.

The lateral cords, holding the customary position at the sides of the animal, pass backward through the body and finally terminate in ganglionic enlargements on each side of the pericardium near the tip of the seminal receptacle. The commissure uniting them passes out from the hinder end of each ganglion and crosses dorsal to the intestine. One or two nerves also pass out from each enlargement, but in the confused mass of muscle they have been traced but a short distance.

The pedal cords after traversing the body gradually approach each other in the posterior end of the animal and terminate in two ganglionic masses on each side of the mid line a short distance in front of the two groups of spines that project into the ventral furrow. There are strong indications that these posterior ganglia are united by a commissure. Owing to the difficulties of observation no other pedal commissures have been discovered and for the same reason lateropedal connectives have not been found with certainty though at various points there are indications that such exist.

The posterior sense organ is located at the extreme hinder end of the animal in the mid line. At this point the hypodermal cells, unchanged in appearance, approach near to the outer surface of the body and there become continuous with a sensory epithelium composed of slender fairly dense cells in which the elongated nuclei hold an almost median position (Plate 32, fig. 11). Over the exact centre of this area the cuticle is exceedingly thin but gradually increases in thickness as the outer limits of the organ are approached, and contains considerable numbers of small spines that in both specimens overarch the sensory cup. Numerous muscles and connective-tissue fibres attach to its under surface and in the meshwork thus formed blood corpuscles and nerve cells occur in moderate quantity, the latter probably connecting with branches from a strong nerve that may be followed into close proximity to the posterior pallial commissure.

Alexandromenia agassizi, sp. nov.

Six specimens, one badly mutilated, of this species were dredged in 460 fathoms (Sta. 2992) near the Revillagigedo Islands off the coast of Mexico. All save one, clinging to a fragment of some land plant (Plate 2, fig. 5), were unattached and nothing is known of their mode of life. The smallest specimen is yellowish white; the remainder, of larger size, are yellowish brown.

The largest individual measures 25 mm. in length and 5 mm. in average diameter in the middle of the body; and of the five remaining specimens three are of about this same size. The smallest is in an uncontracted state and is 22 mm. in length and 3 mm. in average diameter. As may be seen in Plate 2, fig. 5, the head is not distinct, usually bluntly pointed, and readily distinguishable from the posterior end where the borders of the cloacal opening are widely expanded, in one specimen especially (Plate 5, fig. 5), exposing the gill plates, about 40 in number. A dorsal sense organ is visible in sections but not in surface view.

The body is surrounded by a cuticle 0.108 mm. in thickness, and as in the preceding species, this is largely occupied by papillae (Plate 33, fig. 5) and spicules of two varieties (Plate 37, fig. 9). Of the latter those of one type project from the hypodermis, with which they remain connected, almost at right angles and protrude freely from the surface of the body. The others, needle-like, relatively small, and slightly curved, form from five to seven irregular layers almost at right angles to the first named spines.

The papillae are fully as numerous as in the succeeding species and the constituent cells are approximately half as abundant; but the differentiation into stalk and expanded part is not so sharply defined (Plate 33, fig. 5). In many cases the base of the stalk is of great width and expands but slightly as the surface of the body is approached, the papilla in such circumstance having a club-shaped appearance. Even in the more typical forms the departure from such a state of affairs is not marked. The cells appear to be all of one type in the distal portion, at all events the nuclei are of essentially the same size, though they vary considerably in shape, and are surrounded by masses of yellowish green pigment.

On the ventral surface, especially in the region of the mouth, gland cells appear in the hypodermis. In their early stages each is pear-shaped, the stalk being inserted among the hypodermal cells, while the distal portion contains a lightly staining almost homogeneous secretion. Later this product becomes more abundant, swelling the cell to twice its original size, and a granular mass appears to make its way by a very delicate pore to the exterior, though this has not been demonstrated to my entire satisfaction.

The main portion of the anterior pedal gland is located between its outlet into the ventral furrow and the radula and its supports. At this point the cells are continuous across the mid line and laterally extend as thin plates compressed between the body wall and the prodigious salivary glands (Plate 20, fig. 4). Posteriorly they separate into two groups which pass without any recognizable line of demarcation into the posterior pedal gland. The cells composing it are of the usual pyriform type, densely filled with intensely staining secretory products, and are arranged into irregular groups or lobules. In the customary fashion the ductules from each cell open by an intercellular canal into the anterior end of the pedal furrow.

At the point where the anterior pedal gland opens to the exterior the ventral groove becomes a deep excavation (Plate 7, fig. 3) the area of whose walls is increased by the presence of extensive dorso-lateral outpouchings and numerous folds coursing from the roof half way down the sides. On the posterior face

several folds arise and posteriorly extend along the groove to the cloacal cavity. These are not constant for at their first appearance they are eleven in number (Plate 20, fig. 9), soon decreasing to nine and gradually to five in the posterior half of the animal. Each is penetrated by a loose meshwork of muscle and connective-tissue fibres, through which the multitudinous ductules of the pedal gland take their course, together with many corpuscles from the overlying sinuses. The component cells are high and columnar, especially the outermost which contain small quantities of yellow pigment.

The opening into the atrium, holding its customary subterminal position (Plate 7, fig. 3), leads into the atrial cavity whose walls are differentiated into the usual ridges (Mundleisten) and cirrose area. As in *P. hawaiiensis* the outermost ridge is accompanied throughout its anterior half by a prominence, ill defined, and yet evidently sensory since it is composed of slender cells with basal nuclei resting upon a rod-like group of ganglion cells. In the posterior half of the lips this structure becomes more indistinct and finally blends indistinguishably with the outer atrial ridge.

Of the two large atrial ridges the outer is of large size and skirts the cavity save on its posterior face. It is supported by an abundance of connective-tissue fibres associated with a scant amount of muscle bands among which small blood sinuses make their way. The halves of the dorsal ridge arise independently of each other in the mid line on the roof of the atrial cavity. At first very low they rapidly increase in height (Plate 20, fig. 1), but behind gradually disappear in the neighborhood of the opening into the pharynx. Blood sinuses penetrate into their interior and probably in life increase these organs to a very considerable degree. On each side of the mid line in front and hanging from the roof of the cavity are two pairs of large papillae springing from the outer and inner ridges respectively. The epithelial covering is composed of columnar cells whose distal half is filled with golden yellow pigment.

Each cirrus arises independently as a finger-shaped process of the atrial wall with an average length of 0.3 mm. It is composed of cells about twice as high as wide, closely packed with yellow pigment, arranged about a central cavity within which it is occasionally possible to follow a nerve fibre.

The opening of the mouth into the pharynx is guarded by a circular fold beyond which the canal passes dorsally until in the neighborhood of the radula where it bends at right angles and passes directly backward to join the stomach-intestine. Throughout its entire extent its internal lining is developed into many folds, large and small, often exceedingly wavy and of most complicated appear-

ance in sections. In front of the radula especially, large projections appear and, as will be more fully described presently, afford an outlet for the two sets of salivary glands. The character of the pharyngeal epithelium undergoes minor modifications at various points, but in general it may be said that the constituent cells range in size from cubical bodies to others three times as high as wide, are devoid of cilia and are bounded by a well-defined cuticular sheet.

The salivary glands, which probably are homologous with the dorsal set in other Neomenina, are in this species remarkable for their size and extent. With the exception of a few scattered groups of cells the main portion is distributed in the form of a wide band encircling the pharynx from immediately behind the brain to the radula (Plate 7, fig. 3, ds). So far as may be determined from a single specimen all the cells are pear-shaped and are grouped into club-shaped lobules of various sizes. In the expanded part the cells are one layer thick and surround a central canal down which the ductules make their way to open by intercellular canals into the pharynx.

From transverse sections there are indications that a portion of the gland located on the dorsal side of the pharynx immediately behind the brain differs in character from the remaining portion. The follicles are more slender than those of adjoining regions and the glandular products in the early stages of their development are of lavender color and markedly different from the yellowish pink substance elsewhere. All the follicles of the dorsal salivary glands of whatever character are supported by numerous muscles forming the pharyngeal wall and by connective-tissue bands between which numerous blood sinuses are present.

The glands which probably correspond to the ventral salivary of other Solenogastres although in this species their outlet into the pharynx is somewhat more in front of the radula than usual, are enormously developed. As may be seen (Plate 7, fig. 3, sg.) they extend from the brain to a point considerably behind the radula where they entirely surround the alimentary canal and elsewhere overlap it to a very considerable degree. As in the dorsal group the gland is composed of thick-walled follicles, of large size, and from each pyriform cell a ductule leads to its intercellular outlet. Owing to the great bulk of the lobules and the remoteness of the greater number from the main duct (leading into the pharynx) this latter canal is provided with numerous branches (Plate 26, fig. 9) which come in contact with the majority of the follicles where each ends blindly. These minor ducts are lined by an epithelium in which the cells are of two distinct types. In the inner half, through which the ductules make

their way, the cells are very high and slender and the cytoplasm vacuolated. In the outer half the cells are not over one third as high and the protoplasm is relatively compact.

As just noted the branching ducts of each side unite into a single tube, which opens into the bottom of a deep depression on the side of the pharynx. From the base of this pit a large conical papilla (Plate 36, fig. 10), whose surface is thrown into five or six circular folds, projects inward, in life its tip probably extending as far as the opening into the pharynx. It is practically solid, consisting of connective tissue and several muscle fibres which probably act as retractors. The ductules of a very few adjacent follicles make their way into this protuberance and are accompanied by similar tubules from some of the dorsal salivary-gland cells. These slender canals make their exit at several points, from the tip and by means of pores ventrally placed on the circular folds. The last named openings connect with small canals (perhaps one sixth the length of the circumference of the fold), located between the cuticle covering the papilla and the underlying epithelium. There may be other exits but if so they are of small size and are invisible in the material in hand.

Attached to the pharynx, between these large glands (sg.) and the stomach-intestine another extensive set occurs (Plate 7, fig. 3, and Plate 20, fig. 2) that are difficult to homologize. They consist of numerous pyriform cells, highly vacuolated or containing masses of some secretion of a pinkish shade, arranged in the form of lobules bounded by muscle and connective-tissue fibres. The ductules pass to the pharyngeal epithelial lining through which they open by intercellular channels.

The radula is relatively small and is located on a tongue more than usually pointed. It is of the monoserial type (Plate 34, fig. 5) and as far as may be determined from transverse sections, comprises between forty-five and fifty-three transverse rows. Each tooth is a narrow rectangular plate bent to form a very obtuse angle. The odontoblasts are of the usual columnar type. The radula sac is supported by ten or fifteen pairs of large cells, probably turgid in life, filled with a highly watery secretion, surrounded by connective tissue and muscle fibres. These last named elements are part of bands, too complicated to allow of reconstruction, that attach to the pharyngeal wall, the radula, or the sheath of the salivary glands.

The gonad, with the usual relations, extends from a short distance posterior to the radula to within a short distance of the front end of the pericardial cavity. In common with other hermaphroditic Solenogastres the organ in this species

is paired and the eggs are developed along the septum while the spermatozoa arise more externally where the walls are often greatly folded. Posteriorly the halves of the gland narrow greatly and assume the form of comparatively slender canals (Plate 7, fig. 5), which communicate with the pericardium by wide openings. Their epithelial lining is apparently ciliated and is fashioned into several low longitudinal ridges.

The coelomoducts arise from the postero-lateral borders of the pericardium as comparatively wide canals, which first extend downward and then forward to join the so-called shell gland at the point where the seminal receptacles are located. As usual the shell gland of one side joins the corresponding organ of the other and after narrowing to a slender tube opens into the cloaca in the mid line.

The walls of the coelomoduct (see Plate 20) in the region of the pericardium are comparatively thin, but one third the distance to the seminal receptacle they become thicker, the cells more slender and the ten to fifteen longitudinal folds more pronounced, a state of affairs which continues to the shell gland. Cilia are certainly present at various points and it is probable that they exist throughout the duct between the pericardial cavity and the seminal receptacle. In the same section small quantities of a glandular secretion are developed having the form of minute granules which show at first a distinctly acid reaction but after their discharge become more or less confluent and alkaline. Minute quantities of spermatozoa are also distributed throughout this same division of the duct.

In the single specimen examined the seminal receptacle is a small disc-shaped sac attached to the coelomoduct where the inner and outer portions meet. It is wedged between the body musculature and the shell gland and the slit-like lumen contains a few spermatozoa only. The cells composing the walls are comparatively low and are glandular, the clear secretion, small in amount, giving the cytoplasm a vacuolated appearance.

In this species the shell gland is of enormous size, filling practically all the space between the digestive tract and pericardium dorsally and the body musculature ventrally and laterally. As figured, Plate 20, each half is penetrated by a duct, of about the diameter of the foregoing section, through which the secretion from the surrounding glandular portion makes its way. In the neighborhood of the cloaca these ducts emerge from the gland, unite with each other, and forming an S-shaped loop in side view open into the cloaca by a very narrow pore.

The component gland cells are arranged into numerous lobules, which generally extend from the surface of the gland to the main central duct. These are separated from each other by delicate connective-tissue sheaths, which frequently contain small blood sinuses, and are traversed by a slender canal which apparently does not function as a duct. The evidence is not altogether conclusive but from a careful study of sections it appears that the secretion does not pass through the cavity of the lobule, but is contained in delicate ductules which arise in the gland cells. Arriving at the central cavity of the gonoduct the darkly staining secretion makes its escape through the lining epithelium by means of intercellular openings.

The epithelium of the main duct is composed of high columnar cells which contain a finely granular lightly staining glandular substance. About the terminal section of the coelomoduct, where the epithelium become lower and the secretion scant in amount, a heavy sheath of circular muscles appears and continues to the cloacal cavity.

As might be expected in an animal of the size of this species the circulatory system is well developed and of more than ordinary complexity owing to the large number of sinuses which hold positions in and around the various systems. The heart, having the usual position, consists of two distinct divisions (Plate 7, fig. 5), an auricle and ventricle. The walls of both of these are of uncommon thickness, but otherwise present no especially noteworthy features. They are connected by a tubular stalk which projects slightly into the cavity of the ventricle and may serve as a valve.

From the front end of the ventricle blood passes through numerous openings in the somatic musculature to unite into one tube, the aorta, which from the outset appears to lack any trace of an endothelial lining. As it courses forward dorsal to the reproductive gland it originates numerous vessels which ramify through the body wall or passing ventrally between the halves of the gonad forms a subgenital sinus. In the head region it expands considerably and communicates with extensive lacunae in and between the body wall and the alimentary canal. The blood in these spaces makes its way to the ventral surface where it unites into one main canal, immediately ventral to the gut, which connects also with several small channels coursing along the folds in the ventral furrow. At the posterior end of the body this ventral sinus courses dorsally, keeping close to the under surface of the gut, and when opposite the junction of the auricle and ventricle it divides into two short branches which pass backward on each side of the rectum. These last named vessels are very

short and soon divide into a large number of minor sinuses communicating with the gill folds.

Each gill plate is merely a ciliated fold of the cloacal wall with which it connects anteriorly and laterally. The blood enters the anterior border usually, and coursing through the narrow enclosed spaces finally makes its way laterally to the body wall. Here it unites with other vessels of similar origin and finally by means of a large canal passes dorsally and enters the heart immediately after uniting with the corresponding sinus from the other half of the body.

The blood corpuscles are spherical bodies, .0074 mm. in diameter, hyaline in appearance and containing a small, dense nucleus. The leucocytes are remarkably infrequent, unusually compact, but otherwise devoid of any noteworthy features.

About the bases of the gills there are great accumulations of gland cells (Plate 36, fig. 19) occupying spaces in the meshwork of muscle strands between the folds and the body wall. They project somewhat into the sinus of each gill plate, and are occasionally penetrated by blood sinuses, but there is no trace of any outlet nor is there any indication of their possible function. Each cell is approximately 0.01 mm. in diameter, and contains a small, spherical nucleus imbedded in slightly vacuolated, granular cytoplasm.

The nervous system of this species is in an excellent state of preservation, and as the nerves in many parts of the body are more than usually well defined considerable attention has been devoted to this portion of the anatomy. The location of the brain and principal ganglia are the same as in *Dorymenia acuta* for example, but in the distribution of certain of the nerves differences appear which are here described. The brain (Plate 12, fig. 5) is relatively small, but anteriorly gives rise to the usual number of nerves distributed to the atrial cavity and the neighboring body wall. The united connectives of the lateral, pedal, and labio-buccal systems enter from the side. The first two connectives become differentiated a short distance laterally and pursue their usual course through the body. The labio-buccal connective springs from the lateral connective posterior to the union with the pedal and holds its customary position at the sides of the pharynx.

In Dorymenia there is a large nerve fibre arising from the anterior end of the lateral ganglion and is distributed to the precerebral ganglia about the bases of the cirri; in the present species it is totally lacking. In both species nerves arising from the pedal ganglia are distributed to the walls of the pedal-gland outlet. Numerous connectives unite the lateral and pedal ganglia, and are far from being regular, in several cases uniting with neighboring connectives by

delicate branches. Usually the most anterior connective is of the largest calibre, but in the present instance the first two or three are extremely tenuous, not over one third the diameter of the succeeding connectives. Dorsal nerves from the lateral ganglia are numerous but in no instance have they been traced to the mid dorsal line.

The labio-buccal system is probably more extensive than is shown in Plate 12, fig. 5, for owing to the great width of the muscular pharynx and the abundance of salivary glands closely crowded together it is very difficult to trace nerves for any considerable distance. The connectives may be readily followed to the ganglia at the sides of the pharynx, and the commissure uniting these is as readily demonstrated, but a different state of affairs is met with elsewhere. Before uniting with the labio-buccal ganglia the connectives far out on the external face of the salivary glands enter a ganglionic enlargement on each side from which two nerves originate. One of small size disappears almost immediately among the glands; the other of much larger size passes in toward the mid line, but becomes lost in the darkly staining secretion of these same glands. From the dorsal side of each labio-buccal ganglion a small nerve arises that gradually extends to the lateral border of the pharynx which it crosses to form a commissure. At various points throughout this entire system exceedingly small nerves arise and probably innervate the neighboring regions but their destination is not certain.

In the posterior end of the body the lateral nerves become so crowded against the body wall, owing to the huge shell gland, that it has been impossible to trace connectives in this region. Opposite the posterior end of the heart they expand greatly (Plate 12, fig. 6), and originate several nerves distributed more posteriorly as well as the suprarectal commissure. Two connectives, the posterior one of large size, unite with the posterior end of the pedal cords. In the mid line the suprarectal commissure develops a nerve that passes to the base of the dorso-terminal sense organ, to which it sends a small nerve, whereupon it proceeds backward distributing fibres to the dorsal gill plates. The large branches, springing more laterally from the posterio-lateral enlargements, branch repeatedly and in many places delicate offshoots have been found entering the branchial folds. Plate 12, fig. 6 represents the more important of these whose number and origin is correctly shown though the branching is somewhat diagrammatic. With this exception the nerves and ganglia shown are reconstructed carefully from micrometric measurements.

The pedal ganglia have not been examined in the middle of the body, but

elsewhere they are united by strong commissures. In the region of the shell gland this organ is entered, and probably innervated, by several fibres which arise from these ganglia. Posterior to the last of the latero-pedal connectives three or four small branches pass into the muscles about the external reproductive opening. No nerves have ever been followed from this source into the region of the branchial lamellae, and if any are derived from this source they are of very small size.

Alexandromenia valida, sp. nov.

Four specimens of this species (Plate 3, fig. 3) were collected off the coast of southern California from the following Stations: 2980, 4382, 4389, 4391. The depth ranges from 603–1350 fms. and in every case the bottom was green mud. All the specimens were unattached so that nothing was learned of their habits. The measurements of the largest specimen (Sta. 4389) are as follows: length 32 mm., dorso-ventral diameter of head 3 mm., of cloacal region 3 mm., average diameter of body 3.5 mm.

The head is not distinct from the body but is characterized by a more pointed appearance than the posterior end, and in all the specimens the borders of the cloacal opening are slightly expanded, exposing, to a slight extent, the gill folds. The atrial opening is relatively small and its forward border is almost level with the front end of the animal. A pedal furrow extends along the ventral surface of the body and posteriorly becomes continuous with the cloacal cavity. Anteriorly, for about 1 mm. extent, it expands and allows the escape of the anterior pedal gland secretion (Plate 21, figs. 2, 4) which, in the type, fills the opening and extends posteriorly some distance along the ventral furrow. The general color of the body is light yellow.

A well-developed dorsal sense organ is present, situated in the type about 2 mm. from the posterior end of the animal. It is in the form of a shallow pit and is especially conspicuous in surface view on account of the numerous hypodermal papillae which surround it.

The body is surrounded by a cuticle, 0.16 mm. in thickness, which is crowded with innumerable spicules and papillae of large size (Plate 33, fig. 8). The hypodermal layer is concerned almost wholly with the development of these structures, the portion probably responsible for the formation of the cuticle being limited to a few cells packed between the bases of the papillae and developing spines. Everywhere the hypodermal elements are of small size, and though excellently preserved are not favorable for study.

As just noted the papillae are of enormous size and in a fully developed

condition contain not less than 100 cells. Of these fully twenty-five are located in the stalk while the remainder hold positions in the expanded portion. This last named section is relatively compact and lacks the spaces and pseudopodia-like processes characteristic of the majority of Solenogastres. The cells composing it are of two distinct types, one containing small spherical dense nuclei and another in which the nuclei are of twice the diameter of the first, and stain but faintly in haematoxylin. The cell boundaries are invisible and it is consequently impossible to determine if these differences are correlated with others. The cells with the small nuclei contain a few relatively large yellowish pigment granules, and there is some evidence, though not wholly conclusive, that this secretion is absent from the cells of the remaining type.

Of the two kinds of spicules the larger (0.189 mm. long) projects from the hypodermis almost at right angles and its pointed extremity projects slightly above the surface of the body. As Plate 37, fig. 11 shows these spicules are hollow and remain constantly in contact with their matrix cells, which are several in number and in their general appearance and relations are not unlike those of *P. hawaiiensis*.

The second type of spine is many times more numerous than the one just described. Over the body generally all are of essentially the same size (0.135 mm. average length) and in their needle-like appearance resemble the long spines of Proneomenia, Strophomenia, etc., with which they are probably homologous. Without any very definite arrangement they form several layers parallel with the hypodermis.

The anterior pedal gland occupies practically all the space between the body and pharyngeal walls between the brain and the radula. The cells are of various sizes but average 0.189 mm. in diameter and are so densely filled with secretory products that all other elements of the cell are invisible. From each a duct leads to its intercellular opening into the anterior end of the ventral furrow.

The outlet of the anterior pedal gland, the widened end of the pedal furrow, is of large size, and its walls are fashioned into numerous folds (Plate 21, fig. 2) to afford sufficient surface for the exit of the many ductules. On the roof of the cavity two short longitudinal ridges, almost papilla-like, are present and from these numerous much smaller folds extend down the sides of the chamber to the external opening. After treatment with haematoxylin the secretion of the pedal gland becomes almost black, indicating an alkaline reaction, while the cells lining the outlet of the pedal gland (between which the ductules make their exit) are bright pink in color and therefore distinctly acid in their reaction.

The cells of the posterior pedal gland are of comparatively small size, but otherwise are essentially the same as those of the anterior pedal gland. As usual they open by separate intercellular exits into the pedal furrow.

In several species of Solenogastres the foot is accompanied by two longitudinal ridges, modifications of the hypodermis. In the present species the median projection is bordered by two prominences on each side. All are of essentially the same size and appearance, being thin folds of epithelium into which a few muscle and connective-tissue fibres project. No blood spaces occur within them and at their bases the secretion from the pedal gland finds its outlet.

The atrial cavity in the only specimen examined is of limited extent (Plate 11, fig. 3), but it possesses ridges of large size that together with the cirrose area presents a very characteristic appearance. The indistinct prominence, which in some species accompanies the outer ridge, is not sharply defined, being recognizable solely by the rod-like group of ganglion cells in the customary position. The outer atrial ridge proper is of large size, and as a much folded, horseshoe-shaped elevation surrounds the atrial cavity except posteriorly. The inner fold is of inferior size and consists of two ridges which arise independently on the roof and posteriorly diminish in size and gradually disappear. Their epithelial covering consists of high slender cells with elongated subcentrally placed nuclei distal to which the cytoplasm contains quantities of light yellow pigment. Internally the folds are supported by strands of connective tissue with a small admixture of muscle fibres among which well-defined blood sinuses pursue their course.

The cirri arise singly from the atrial wall and are of more than ordinary thickness. As usual each consists of an outgrowth of the buccal wall, composed of more or less cubical cells in which the yellowish brown pigment is so abundant that it usually conceals the nucleus. The cavity of each cirrus is very narrow, allowing the passage of a nerve strand but not of the blood.

The buccal cavity or pharynx, separated from the atrial cavity by a circular fold (Plate 11, fig. 3), is an irregular cavity whose general appearance and relations are represented in Plate 21. The walls throughout are produced into numerous wavy, more or less longitudinal folds, lined with a thin cuticular sheet. In the middle third, which contains the radula, the folds become more distinctly longitudinal, but more posteriorly they once more become very irregular.

As in *A. agassizi* there are three sets of salivary glands, and as may be seen in Plate 21, figs. 2, 4, in arrangement and size, they are essentially the same as

in the foregoing species. The smallest dorsal glands (dsg) are more or less imbedded in the pharyngeal wall from the cirrose cavity to the posterior end of the radula sac. Each consists of an aggregation of well-marked pyriform cells usually charged with a finely granular darkly staining secretion. In some of the larger groups the secretory products are not so clearly granular and have a more reddish cast, in this respect and in general appearance resembling the second type of dorsal salivary gland.

The second species of gland (sg) is in reality a paired structure each half consisting of about two dozen lobulate glandular bodies united by as many branches of a main duct which opens into the pharyngeal cavity. It appears probable that each organ arose in the embryo as a diverticulum of the gut, and subsequently developed outgrowths in which some of the cells became glandular. These retaining their connection with the lumen of the duct elongated greatly, became pyriform and formed the lobule of the completed gland. As in *A. agassizi* the canal in each lobule develops small lateral branches and in any case the duct holds a superficial position.

The course of the main duct, which lies to the outside of the glands is shown in Plate 21, fig. 2. It opens at the base of a corrugated papilla enclosed in a diverticulum of the pharynx that in turn opens at the forward border of a broad papilla on the pharyngeal wall (Plate 11, fig. 3). As in the foregoing species the papilla contains a few small canals which open on its surface, but their inner connections are difficult to trace. They appear to be the outlets of a number of small glands belonging to the first type which, as noted above, approach the second in the form of the cells and the character of their secretion.

The tubules of the third set (gl) are in form and position like those of *A. agassizi*. The secretion is more abundant and more granular and darkly staining, giving them a denser, more compact appearance, but this set is not voluminous as in the preceding species.

The radula is of the distichous type (Plate 11, fig. 3, Plate 34, fig. 14) and contains approximately thirty-four rows of teeth. These are developed by large numbers of exceedingly slender odontoblasts, and immediately after their formation are enveloped in sheaths composed of numerous so-called enamel cells. Both of these groups blend with cells that become smaller as the opening of the radula sac is approached.

At the forward border of the radula the cells of the pharyngeal wall become more columnar, less dense, and their nuclei assume a more slender shape. Appearances suggest a subradular sense organ, but it lacks the definiteness of this

structure in *Proneomenia hawaiiensis* for example, and is apparently not innervated by a well-defined subradular nervous system.

The oesophagus opens at the summit of a papilla (Plate 11, fig. 3) into the stomach-intestine, which manifests no especially noteworthy features save that its lining is of such thickness that in preserved material it reduces the cavity to a narrow slit. In the posterior end of the body the gut narrows to a vertical slit as it passes between the anterior ends of the shell gland then becomes a circular canal of small size that opens into the cloacal cavity dorsal to the external reproductive opening.

The circulatory system is almost the exact counterpart of that in *A. agassizi*.

The reproductive system is likewise practically identical with that of the foregoing species. The pericardial cavity is smaller, and the inner ends of the coelomoducts are more slender, but they rapidly increase in size and their walls become more than usually folded. The shell gland, especially its posterior half, is more distinctly lobulate and somewhat more acid in reaction. The seminal receptacles are considerably larger; but neglecting these differences the two species agree closely so far as this system is concerned.

The nervous system is not especially favorable for study and for this reason only the more obvious portions have been examined. In all essential particulars these closely resemble homologous structures in the foregoing species.

Halomenia gravida, sp. nov.

This species is represented by two individuals taken off Simushir Island of the Kurile group at a depth of 229 fathoms (Sta. 4804). Both were discovered in dead barnacle shells and are evidently free roving forms. The larger specimen is 11 mm. long by 1.6 mm. average diameter and the length index 7:1 is characteristic also of the smaller one. The anterior cirrose section of the gut, or the atrium, is separated from the succeeding portion by a ridge (Plate 5, fig. 3) covered with the spiculose cuticle investing the body. Posteriorly the pedal groove is continuous with the cloaca which like the atrial opening, extends far up toward the dorsal surface of the body. The color is light yellow shading to nearly white in the head and cloacal regions (owing to compact muscles) and along the mid dorsal line where the gonad is situated. A dorsal sense organ is present (Plate 22, fig. 12), and is remarkable for its large size and from the fact that it is more anteriorly located than is usually the case with other species, being placed opposite the forward cloacal wall.

The cuticle, surrounding the body, is of average thickness (Plate 32, fig. 4), but is actually rather scant in amount owing to the large numbers of spicules (Plate 22, fig. 13) imbedded in it and to the papillae many of which are of unusual size. On the ventral side of the body the unmodified hypodermal cells, those which are probably largely responsible for the development of the cuticle, are comparatively few in number and are crowded between the bases of the papillae, but dorsally they become more numerous and may be seen to possess a cubical form and no especially noteworthy features. Owing possibly to differences in age the papillae vary greatly in size but all are constructed on essentially the same plan. As may be seen (Plate 32, fig. 4) the stalk is composed of an outpushing of hypodermal cells and is usually shorter in the larger papillae. It is surmounted by the usual balloon-shaped group of cells, which certainly number not less than one hundred in the larger organs. Each cell is greatly elongated, vacuolated in its outer portion in preserved material, and contains a spindle-shaped, basally placed nucleus. In several cases the cavity of the stalk is traversed by a delicate fibre, sometimes enclosing a nucleus, which appears to be a nerve.

In this species the stomach-intestine is related in a remarkable way to the cuticle and papillae but for what purpose I cannot say. On the dorsal surface of the smaller specimen and in the region traversed by the mid gut there are not less than twenty pairs of small rounded knobs of light yellow color, forming one longitudinal line on each side of the mid line. These are not distinctly visible in surface views of the larger individual, but in sections they are seen (Plate 22, fig. 1) to be evaginations of the dorsal wall of the intestine which protrude through definite openings in the somatic musculature and extend half way to the outer surface of the body. Each is in contact with the under surface of a circular disc-like patch of hypodermal cells having the appearance of a modified papilla. The stalk is absent and the cells are relatively low, but some are distally vacuolated and are not the compact, cubical elements of the unmodified hypodermis. Surrounding the point of attachment of gut and papilla is a small ring-shaped blood sinus, frequently containing corpuscles. The relations of these various elements are represented in a typical condition in Plate 32, fig. 5. Concerning their mode of operation it appears probable that the pressure of the blood in the sinus causes a protrusion of the papillae and the attached liver lobe, but for what possible reason I cannot say.

The spicules, whose general shape is shown (Plate 22, fig. 13), are of various sizes in a mature condition even in the same locality. These are intermingled

and lack any very definite arrangement further than that they encircle the enormous papillae, giving the animal as seen under low magnification, a mottled appearance.

The anterior pedal gland occupies the major portion of the space included between the gut (Plate 22, fig. 1), and body wall from the level of the brain to the stomach-intestine. Its cells are comparatively small but the secretion is abundant, enabling one to follow in many cases the slender ductule to its opening into the anterior end of the pedal furrow. The walls surrounding this external outlet are unfolded (Plate 22, fig. 1), highly ciliated and form a cavity of more than usual size. From its posterior border two ridges develop (Plate 22, fig. 2) and extend along the pedal furrow to within a short distance of the cloaca, where they disappear though the furrow, reduced in size, becomes continuous with the cloacal cavity.

In surface view it is possible to detect slight folds in the exposed cloacal wall which in sections may be seen to become of much greater height within. These, twenty-six to thirty in number, at first hang freely in the cloacal chamber (Plate 22, fig. 11), but more anteriorly they become attached to the wall of the rectum, and yet farther forward some of the dorsal ones extend into the cavity above the rectum dividing it into a corresponding number of small crypts (Plate 22, fig. 8). In these last named spaces, and between the folds for some distance more posteriorly, upwards of twenty embryos have taken refuge and undergone the first stages of their development protected by the parent. The epithelium of the basal half of each fold in contact with the embryo is low and seemingly non-ciliated, while that of the distal half assumes the high columnar, ciliated appearance characteristic of such organs in several other species.

As noted previously the cirrose section of the gut, or the atrium, opens subterminally and has no direct connection with the remainder of the digestive tract. Its cavity is largely obscured by the thick-walled, large ciliated ridges which hold the usual position and define the cirrose area. The cirri are comparatively short and thick set and are usually united by their bases in groups of two or four. Their cells are of the customary pigmented type and surround a lumen of exceedingly small calibre.

Immediately behind the opening into the atrium the cuticle surrounding the body becomes continuous across the mid line for a short distance, and still more posteriorly breaks through to form a second opening, probably the true mouth. This aperture leads into an irregularly shaped cavity (the general arrangement shown (Plate 5, fig. 3), whose walls, seemingly ciliated throughout,

are developed into a complicated series of ridges. In the customary position a distichous radula is present and though of small size is typical in all essential respects. It rests upon a delicate though perfectly distinct basement membrane and is produced by odontoblasts at the bottom of a shallow sac. There are, so far as may be determined from cross sections, about twenty-four rows of teeth which present the appearance represented (Plate 34, fig. 12).

On each side of the forward limits of the radula sac the narrow ducts of the ventral salivary glands open into the digestive tract and on the other hand lead right and left into a reservoir extending far toward the dorsal side of the pharynx. Each of these cavities is surrounded by a gland (Plate 22, figs. 2, 5), composed of multitudes of small, pyriform cells grouped, by means of delicate connective-tissue septa, into lobules of various sizes. The ductule from each cell makes its way to the wall of a reservoir into which it pours its granular, moderately staining secretion by way of an intercellular opening.

Beyond the radula the alimentary canal courses dorsally and opens into the stomach-intestine. In front of this junction a coecum extends far forward and as noted previously develops on each side of the mid line diverticula which pierce the body wall and come in contact with the under side of what appear to be modified papillae. These are developed also by the stomach-intestine throughout its entire extent. A further peculiarity of the mid gut exists in the form of numerous small secondary outpouchings of the wall of the ordinary gut pouches which give in cross section a complicated appearance to this region (Plate 22, fig. 3). The dorsal wall of the intestine, in contact with the gonad, is relatively low and heavily ciliated. At the level of the forward pericardial wall the gut narrows rapidly, loses its glandular character, becomes ciliated and by a relatively small pore opens into the cloaca.

The position of the heart, its relation posteriorly to the branchial folds and anteriorly to the aorta are typical. As is seen (Plate 3, fig. 5) it consists of two divisions united by a small canal apparently provided with a valve. Both portions are moderately muscular, and lodge in the meshes of the musele bands numerous large, irregular cells which have the appearance of blood forming elements. The aorta, extending anteriorly and dorsal to the gonad, supplies the last named organ with many well-defined ventral branches which, as in *P. hawaiiensis*, pass ventrally along the mid line and reaching the neighborhood of the gut course outwardly and then dorsally to unite with the larger spaces beside the aorta. In the head region this main vessel communicates as usual with sinuses which carry the blood in turn to spaces between the gut and body

wall. Opposite the anterior end of the shell gland the ventral sinus enlarges, and divides, each branch passing dorsally, then posteriorly along the sides of the rectum. Upon arriving at the bases of the cloacal folds they break up into numerous branches each of which enters a fold, passes through it to the neighborhood of the body wall whereupon it makes its way forward to enter the heart.

In appearance, position, and extent the gonad is nowise peculiar. The reproductive elements in the anterior third are wholly male, and in the neighborhood of the pericardium also are great accumulations of spermatozoa while in an intermediate position the great ova, 0.26 mm. in diameter, are most conspicuous objects. Correlated with their great size the ducts leading into the pericardial cavity are of unusually large calibre, being 0.175 mm. in their greatest diameter. The lining cells are low and heavily ciliated.

From the postero-lateral borders of the pericardium the coelomoducts arise, extend outward and forward and enlarging somewhat unite with the shell gland (Plate 3, fig. 5). In the early part of their course the cells, like those lining the pericardium, are low, but more outwardly they become more columnar and form longitudinal ridges of considerable height. At the anterior limits of the shell gland is the opening of the seminal receptacle, which is a simple unbranched tube, empty in the present instance, and is provided with a high ridge extending, like a typhlosole, throughout its length. The cells composing this latter organ are slender, triangular elements which when combined form a fan-shaped structure in cross section. A heavy layer of circular muscles ensheaths the seminal receptacle, and a few radiating bands extend from it chiefly to the body wall.

As usual the shell gland is U-shaped and in the present example is fully functional. In the neighborhood of the seminal receptacle its cells are rather low and their secretion small in amount, but half way down toward the mid line they become greatly elongated, and distally contain a finely granular secretion which escapes in large quantities into the lumen of the duct. Upon the fusion of these tubes in the mid line the dorsal wall of the undivided section is composed of cells, also high in form, which during the early stages of glandular activity are filled with a darkly staining vacuolated secretion (Plate 15, fig. 8 and Plate 22, fig. 6). This condition of affairs, mucous cells dorsal and albumen forming elements below, continues to the single median opening in the cloacal cavity.

As noted previously this species broods its young. The eggs, about two dozen in number, have been retained in spaces between the great branchial folds in the cloacal wall and evidently they have come down at different periods

as all stages of development are represented from a 4-cell condition to advanced larvae where the shell and foot are indicated, the fore and mid gut clearly differentiated, the anterior pedal gland developed and to some extent functional, the central nervous system partly outlined (Plate 22, fig. 7). A fuller account of the embryology is planned for a later paper.

The brain, of usual size, holds the customary position above the pharynx. The anterior nerves passing to the cirri, etc., and the pedal, lateral, and buccal connectives have the usual relations. Anteriorly the pedal cords enlarge and are united by a more than usually heavy commissure, and each gives rise to a nerve that passes to the wall of the outlet of the anterior pedal gland. Here and there pedal commissures may be detected, as well as connectives with the lateral cords, but these are usually small and often very difficult to follow.

The labio-buccal connectives are imbedded in the walls of the pharynx and connect with ganglia, of rather small size, located at the sides of the radula. These ganglia are united by a commissure ventral to the pharynx posterior to the radula. The ganglia, and more anteriorly the connectives, give rise to small fibres that may form commissures, as in other species, but their lack of sharpness renders it impossible to trace them more than a short distance into the pharyngeal wall.

In the posterior end of the body the pedal nerves diminish in calibre and disappear beneath the shell gland. The lateral nerves, upon reaching the forward border of the shell gland, pass diagonally inward toward the mid line until they reach the level of the outlets from the pericardium. Here they enlarge (Plate 3, fig. 5) and are united by a commissure passing dorsal to the rectum. The last two connectives between the pedal and lateral cords are of about twice the usual diameter and pass to the inner side of the shell gland. From the posterior superior ganglion several nerves arise that course over the cloacal passage to which they give off delicate fibres, then extend into the somatic musculature and probably are distributed in part to the hypodermis. Near the mid dorsal line two other nerves originate and attached to the forward wall of the cloaca pass dorsally and are distributed through the somatic musculature in close proximity to the hypodermis.

Herpomenia platypoda, sp. nov.

Eleven specimens of this species were taken in the neighborhood of Agattu Island of the Aleutian chain (Sta. 4781) in water 482 fath. in depth. All were attached (Plate 1, fig. 4) to a colony of some unidentified campanularian hydroid

and varied in size from 11 mm. in length and 0.6 mm. diameter to 18 mm. long and 0.9 mm. in thickness. A well-defined dorsal keel extends throughout the entire length of the animal with the exception of the extreme posterior end. In a contracted state both ends are pointed and quite similar, but usually the atrial cavity is opened so that the outer ridges are exposed, thus giving the front end a blunt appearance. The color is white or yellowish white, depending to considerable degree upon the food contained in the alimentary canal. A single layer of spicules envelops the body, the majority being leaf-like in form and biconvex in cross section. A second type with a short stem occurs in the neighborhood of the ventral furrow, and to a less extent over the body generally. The cuticle is more highly developed than is usual with species in this family, and is underlaid by a hypodermal layer of more than usual height beneath the dorsal keel. In their general appearance the component cells resemble those of some of the Chaetodermatidae, being of cubical or rectangular shape, or in the case of what appear to be spicule matrix cells more or less globular except in the region of the keel where they are much elongated.

The anterior pedal gland (Plate 19) occupies practically all of the head region not held by the ventral salivary glands from slightly in front of the middle of the pharynx to the forward end of the body. The crypt into which it opens is typically placed (Plate 8, fig. 1), possesses unfolded walls and is profusely ciliated. Posteriorly the anterior gland joins, without any sharp line of demarcation, the posterior one which continues to the cloaca.

In the anterior end of the body the foot is the merest fold or it may be entirely smoothed out. This latter condition obtains in the posterior half of the body (Plate 19, fig. 10). However, all of the cells retain their ciliated condition though they are more columnar than the ordinary pedal cells of other species.

The atrial cavity is unusually small (Plate 8, fig. 1) and the outer ridges are lacking or are without clearly defined boundaries. The inner elevation on the other hand is a prominent fold, penetrated by blood sinuses, and is composed of cubical cells save along the free border where they are higher, more spongy and heavily ciliated. The cirri, presenting the customary appearance, are arranged in groups of 3–7. The opening from the atrium into the buccal-pharyngeal section is comparatively narrow, being reduced by a large fold springing chiefly from the dorsal side of the digestive tract. Beyond this the canal widens, its lining epithelium becomes considerably folded, and is composed of columnar cells endowed with considerable glandular activity. Still farther inward the wall again develops a circular fold which forms the outer boundary of another circu-

lar groove between it and the muscular pharynx. Through the posterior wall of this groove the ventral salivary glands find their outlet by means of two ducts very closely situated to the mid line (Plate 8, fig. 1, Plate 19, fig. 8).

The ventral salivary glands are unusually large organs completely encircling the gut for part of their course, and occupying most of the space between it and the body wall from their outlet to the junction of the pharynx and stomach-intestine. The cells composing them are pyriform, 0.024 mm. in greatest diameter and are filled with a homogeneous, moderately staining secretion in which the relatively large nucleus holds a more or less central position. The cells are arranged in lobules, and their delicate ductules open by intercellular channels (Plate 19, fig. 13) on each side of the body into a reservoir whose superficial extent is much increased by several folds. The outlet from each reservoir passes to a small diverticulum of the pharyngeal wall into which it opens opposite its fellow and very close to the median plane.

The pharynx is a prodigiously heavy tube whose walls are composed of a compact mass of muscle fibres chiefly circular (Plate 19, fig. 7) lined with high columnar cells developed into upwards of a dozen longitudinal folds. These last named elements contain a weakly staining secretion and are in contact distally with a distinct cuticular membrane. Posteriorly this tube projects some distance into the stomach-intestine, Plate 8, fig. 1. A radula is completely lacking in this species, and it is probable that, as in *Drepanomenia rampyrella*, the secretion of the salivary glands exercises a solvent action on the tissues of the host that are then sucked up by the powerful pharynx though its exact mode of operation is difficult to understand. Nettle cells, from the host, are present in the intestine, in some cases seemingly imbedded in the epithelial cells.

The lining of the stomach-intestine, where the distal portions of the cells bearing the secretion have not been detached, is excessively high, in one specimen almost occluding the lumen. Beneath the gonad is a small median fold apparently ciliated, and showing evidence of slight glandular activity. Ventral to the pericardial cavity the gut rapidly narrows to an almost circular tube of small calibre and opens with the shell gland into the cloaca.

The pericardial cavity, as may be seen (Plate 8, fig. 3), is of moderate size only, and is in large measure filled by the simple tubular heart. The aorta is exceptionally small as are the sinuses generally with which it connects, yet so far as they have been traced their relations appear to be perfectly normal.

The gonad holds the customary position, but is remarkable in several respects. In the first place it is sharply differentiated into two zones in the two

specimens examined, a forward section in which the sex products originate, and a posterior division that serves merely as a duct. This latter portion is exceedingly narrow (Plate 8, fig. 3), upwards of twice the bodily diameter in length, is without any signs of developing germ cells and contains throughout fully developed sperms. The ova and sperms develop in the customary position, but the former are scant in amount and unusually large, almost completely filling the gland.

Especially about the periphery each ovum contains imbedded in the yolk large numbers of clear vesicular bodies (Plate 35, fig. 9), approximately 0.0068 mm. in diameter with an eccentrically placed darkly staining mass usually superficially placed. At first these bodies appeared to be remnants of nutritive cells, possibly modified follicle cells, but subsequent study leads strongly to the conviction that they are portions of fragmented nuclei. In the early stages of ova development these same bodies occur, but are of extremely small size (Plate 35, fig. 6). Still earlier (Plate 35, fig. 7) it has been possible in several cases to find imbedded in very small ova from one to three cells resembling primordial germ cells, and probably corresponding to follicle cells that are known to occur in a few Solenogastres. These nuclei in a slightly older stage become somewhat larger and stain blue instead of light red or pink. The granules assume the vesicular appearance characteristic of later stages and slightly later upon the rupture of the nuclear membrane become scattered throughout the egg. Against the belief that these structures are cells may be urged the fact that in their early development they are much smaller than any cell of the body, measuring not more than 0.0008 mm. in diameter, and secondly there is at no time any sign of a cytoplasmic mass. These granules correspond closely in size and number to the chromatin bodies, possibly chromosomes, that occur normally in the spermatocytes.

In the pericardial cavity the spermatozoa are attached in considerable numbers to the wall especially along the dorsal surface, or at the time of the animal's capture were being swept along in a current passing beneath the heart and outward through the coelomoducts arising from the posterior wall. The dorsal section of each duct (Plate 8, fig. 3) is a simple tube of even calibre throughout, passing downward and forward from the pericardium to unite with the shell gland. Shortly before this union it unites with the duct of the seminal receptacle, which resembles a flask with a long curved neck. This last named organ like the dorsal limb of the coelomoduct is lined with cubical cells possibly ciliated, to which are attached a small number of spermatozoa.

The shell gland is a globular body and almost totally lacks the cornua

prominent in the majority of species. On the sides of the organ the epithelium is comparatively thin but it rapidly becomes thicker above and below owing to the excessive development of numerous gland cells. In this highly developed condition each cell is a goblet-shaped body with very slender stem and a slightly expanded base in which the nucleus is placed. The secretion consists of a granular mass much like yolk in appearance and staining reaction. Among these larger elements slender supporting cells, usually with subcentrally placed spindle-shaped nuclei, occur in considerable numbers. Both of these elements occur on the sides of the organ but as mentioned previously they are very low and cubical or rectangular. Since the distal portions of these cells are dislodged in the apparently normal process of liberating the secretion it is probable that at times these lining cells are of greater height. At the postero-ventral surface of the gland a short narrow duct, whose position and general appearance are represented (Plate 8, fig. 3), makes its way into the cloaca.

Owing to the similarity of the nerves and connective tissue, and muscle fibres, and the consequent difficulty of tracing these to any extent, the nervous system has not been examined.

Dondersia californica, sp. nov.

One immature specimen taken at a depth of twenty-one fathoms off southern California (Sta. 4303) is the sole representative of this species. Owing to the fact that it bore a superficial resemblance to several small nemerteans it was killed with them in corrosive acetic destroying totally all traces of calcareous structures.

The general form of the body is shown (Plate 3, fig. 9). The length is 7 mm. and the greatest diameter 1.2 mm. The pedal groove, and single, included fold, is continuous with the cloaca though at the point of union the former has become very indistinct. The outlet of the anterior pedal gland is a well-marked invagination with highly folded, ciliated walls. In this genus more than one dorso-terminal sense organ is present, two being found in *D. festiva* and three in *D. annulata* according to Nierstrasz ('02). In the present species eleven exist, all constructed on the same plan (Plate 35, fig. 12). Of these five occur along the mid line, and the others are not far removed from it. As Plate 6, fig. 2, shows they are not symmetrically disposed for of the six not in the mid line five are on the left side of the body. Each organ consists of a globular mass of slender cells, with elongated mesially placed nuclei, covered distally with a thin continuation of the cuticle investing the body. From the bases of the cells

fibres, probably muscle and nerve, judging from other species, pass into the underlying tissue.

It is evident from the thinness of the cuticle (Plate 32, fig. 8) that but a single layer of spicules exists in this species and from spaces in the decalcified cuticle it is evident that they are of small size. The hypodermis is comparatively thick and comprises several classes of cells. The most conspicuous, and at the same time the most rare, are gland cells which are generally more deeply placed than the other elements between which their delicate ductules pass to the exterior. These are most abundant on the ventral surface.

At all points there are almond-shaped spaces in the hypodermis which appear to have been filled with a calcareous product, and judging from the cell remnant usually in connection with them, it is probable that they are spicules in process of formation. The cells apparently responsible for the formation of the cuticle are columnar, non-staining elements containing a centrally placed nucleus. Between them are very slender cells with spindle-shaped mesially placed nuclei which may possess a sensory function though this is not definitely established. No papillae are present.

In this species the atrial cavity, provided with cirri and ridges, is entirely distinct from the radula-bearing region which communicates with the exterior by an opening immediately in front of the outlet of the anterior pedal gland (Plate 5, fig. 4). In this forward division the dorsal or innermost of the buccal ridges is lacking; the external one on the other hand is prominent and abundantly ciliated. The cirri are united by their bases into groups of three or four or rarely six. In this enlarged basal part it is sometimes possible to distinguish a few bipolar cells which connect with fibres passing distally through the cavity of each cirrus, and in a reverse direction become lost to view in the vicinity of the ganglionic masses surrounding the cirrose division of the digestive tract.

As just noted this anterior end of the alimentary canal is separated from the succeeding portions by a narrow tract bounded by hypodermal cells and covered with a spiculose cuticle. Whether this division line disappears later in life, the cirrose section then communicating with the remainder of the gut, as is usually the case, it is impossible to say, though judging from the size of the specimen and the profound changes required to bring about such a state of affairs it seems probable that the present arrangement obtains in the sexually mature individual. From the foregoing it develops that what Thiele assumes to be the true mouth is an independent opening communicating in the present instance with a comparatively narrow plicated tube leading into the larger pharyngeal, radula-

bearing portion which in turn connects with the stomach-intestine by a short oesophagus.

Dorsal salivary glands are represented by a small number of pyriform cells communicating with the pharynx immediately behind the level of the brain. Slightly more posteriorly there are other similar cells, but they cannot with certainty be differentiated from the anterior pedal gland. The ducts of the ventral salivary glands open close to the mid line on each side of the forward end of the radula (Plate 23, fig. 5). Distally they make their way, as slender tubes, in a lateral direction and then expanding to twice their initial diameter proceed for a short distance posteriorly. To this expanded portion are connected multitudes of pyriform gland cells arranged somewhat indefinitely into lobules attached to the lateral and ventral walls of the pharynx. In *D. annulata* Nierstrasz ('02) finds numerous cells situated about the ventral ducts; it is probable that they are the salivary cells whose ductules have been destroyed owing to faulty fixation.

The radula is comparatively small and the teeth very transparent so that it is somewhat difficult to discover their exact form. Judging from cross sections each tooth consists first of a basal plate (Plate 8, fig. 8), narrow rectangular in form, and without any connection with the plates of neighboring teeth. This basal bar supports what appears to be a triangular median tooth, but high powers resolve this into a pair of elements closely appressed. It thus appears that the radula is monoserial, each bar bearing a pair of conical cusps. On the other hand the radula may be considered biserial, the basal bar representing a basement membrane, but against this is the fact that the bars are not united with each other. There are not less than twelve teeth if the radula be considered monoserial.

Beyond the radula the digestive canal narrows, becomes folded longitudinally and opens abruptly into the stomach-intestine that after forming a short dorsal and ventral coecum develops the deep, characteristic lateral pouches with glandular walls. In the mid dorsal line the epithelium is differentiated into a fold composed of high, richly ciliated cells which laterally become reduced in height and gradually shade into the non-ciliated digestive cells. The relations of the gut to the cloacal cavity are indicated (Plate 6, fig. 2).

The pericardium is spacious and the heart is of more than average size. The blood from the posterior regions of the body pours into its posterior division corresponding to an auricle (Plate 6, fig. 2), thence into a ventricle-like portion and from there is driven into the aorta. This vessel throughout its entire extent

develops branches, in reality openings, communicating with numerous lacunae in the dorsal crest-like portion of the body. These in turn connect with others of less extent in the lateral regions and through these with the pedal sinus. In the head region the aorta breaks up into several sinuses which make their way through the anterior pedal gland to connect with the pedal sinus and the more lateral spaces just described. In the posterior end of the animal the blood accumulates in large spaces surrounding the intestine and coelomoducts and pours into the heart by means of a sinus passing dorsally on each side in the neighborhood of the reno-pericardial openings. The pedal sinus continues backward to the cloaca then passes dorsally into a space beneath the shell gland and from there into vessels leading to the heart.

The gonad is distinctly paired, the two divisions being in contact only in the middle of the body. Elsewhere they are widely separated by means of the dorsal aorta. In the mid section spermatogonia are fairly numerous and at all points ova are commencing to develop. In the heart region the glands narrow and communicate with the pericardium, which posteriorly communicates also with the coelomoducts opening into the cloaca. The dorsal division of these tubes is comparatively slender and is composed of cubical ciliated cells without signs of glandular activity. No trace of a seminal receptacle is visible unless what appears to be the anterior end of the ventral section may be so considered. This lower division, or shell gland, is composed of rather low columnar cells, tending to form longitudinal ridges, but they likewise are inactive.

Beneath the single opening of the coelomoducts the cloacal wall is developed into an outpouching which in the adult animal may develop copulatory spicula or some gland connected with the egg-laying process, though in the present specimen such functions are purely hypothetical. In shape this outgrowth resembles a thick set **Y**, having a median undivided section which opens into the cloaca and on the other hand connects with a blind pouch on each side of the mid line. The walls are not unlike those of the shell gland, consisting of columnar cells which are richly ciliated.

The cloaca or mantle cavity in this specimen is of unusually small size though it may increase in diameter as the mature condition is approached. A glance at Plate 6, fig. 2, will show that in this species the dorsal commissure uniting the lateral nerve cords is placed uncommonly near the cloacal opening. If in the adult the commissure is customarily placed it might readily be shifted by the active growth and enlargement of the cloaca.

The nervous system is typical. The brain is situated posterior to the atrial

cavity, or cirrose portion of the digestive tract, but with reference to the pharynx it is normally situated. As usual branches pass out from the anterior surface of the brain to unite with ganglionic masses about the bases of the cirri which they appear to innervate and three pairs of connectives unite with the labio-buccal, pedal, and lateral nervous systems. Connectives and commissures, agreeing closely in number with the gut pouches, join the pedal and lateral cords throughout the body. In the region of the cloaca the pedal cords diminish in size and finally disappear, and the lateral cords likewise diminish considerably in calibre, and are united by a commissure which unlike the usual type, is devoid of ganglion cells.

The labio-buccal connectives, imbedded in the pharyngeal wall, attach to large ganglia lateral to the salivary ducts. Owing to the numbers of salivary ductules it is very difficult to trace nerves in this region and determine if there be more than the one commissure uniting these ganglia beneath the pharynx.

Ichthyomenia porosa, sp. nov.

Upwards of twenty individuals of this species were taken in one dredge haul (Sta. 4400) off the coast of southern California, and two additional specimens were captured in the same locality at Station 4402. In both cases the bottom consisted of green mud at a depth of 500–507 and 542 fathoms respectively. All were unattached and there is no evidence whatever regarding their mode of life though it is possible that they may be parasitic upon some of the sea pens (Pennatulidae), of which three species abound in this locality.

There are slight inequalities in size due to differences in age and sexual maturity but the average length is approximately 16 mm. with a diameter of 1.2 mm. The head region is indistinct (Plate 3, fig. 4) and externally is characterized merely by a very slightly greater diameter than that of the body. Posteriorly, in an uncontracted state, the body terminates in a pointed extremity, but in other cases it may become blunt and where the cloaca is opened widely, trumpet-shaped. A pedal groove is present and as usual extends from the hinder border of the mouth to the cloacal opening with which it is continuous. The opening of the anterior pedal gland is usually very distinct, having the appearance shown in Plate 5, fig. 6.

Of the spines covering the body by far the most abundant are exceedingly delicate, of a pointed ovate shape (Plate 37, fig. 1), 0.024 mm. long, and are imbricated, forming a single layer. In the neighborhood of the ventral furrow these are associated with a somewhat similar type, 0.0594 mm. long, with

thickened edges especially on the rounded extremity. Scattered fairly regularly among the first variety are those of the second type, paddle shaped, with short handle and a length of 0.054 mm. Along the ventral furrow they are of a greater length, 0.01 mm.

The hypodermis is apparently one cell thick but the species is peculiar in having the layer developed into many transverse folds (Plate 32, fig. 7) especially on the dorsal surface, and in section these ridge-like elevations render the cell relations obscure. These wrinkles are more pronounced in some specimens than in others, and are usually more prominent in the anterior half of the body. In some cases they are doubtless due to reagents but usually they are certainly normal. The ordinary type of hypodermal cell is very slender, especially in the ridges and is provided with a relatively dense subcentrally placed nucleus. Accompanying these are numerous larger, more globular cells, apparently in large measure empty in preserved material. This may be due to the precipitation of some highly watery secretion, or more probably to the decalcification of some calcareous product.

This species possesses upwards of fifty remarkable organs, apparently sensory, located chiefly about the anterior end of the body in front of the outlet of the anterior pedal gland. All are situated in the ventral half of the animal. Each consists of an invagination of the hypodermis (Plate 24, fig. 12) with an average depth of 0.1 mm. The lining cells are low, very indistinct and are provided with what appear to be very long cilia, which in most cases extend slightly beyond the general body surface. In the most favorable specimens delicate fibres attach to some of the cells but on the other hand they have never been traced to any undoubted nerve. It is impossible to determine their function yet it may be that in life they act as tactile organs like the apical tuft in the trochophore larva.

The anterior pedal gland is comparatively large (Plate 24, fig. 1) and occupies much of the visceral cavity between the atrium and the forward boundary of the stomach-intestine. Its cells are arranged in large groups and are filled with a uniformly granular, lightly staining secretion that after its escape appears as a viscous, darkly staining substance. The posterior pedal gland consists of cells filled with a darkly staining, finely granular secretion clearly distinguished from that of the foregoing group. Anteriorly it rests against, and opens through, the posterior wall of the outlet of the anterior pedal gland, and more posteriorly forms a thin sheet resting against the ventral body wall and opening between five folds in the ventral furrow. Posteriorly these folds very soon disappear save one, the foot, and the accompanying glands diminish greatly.

The atrial opening is subterminal and opens into a comparatively large sized cavity (Plate 5, fig. 6) in which the ridges (Mundleisten) appear to have no existence. On the other hand cirri are present in great abundance and in some specimens project from the mouth for a short distance. These organs may spring directly from the buccal wall, but especially on the sides of the mouth they are borne in groups of from three to seven on stalks containing muscle and connective-tissue fibres between which there are extensive blood sinuses, enabling the animal to project the cirri through the mouth opening. Each cirrus is an unbranched process consisting of small cells with very indistinct nuclei and cell boundaries owing to the large amount of yellowish brown pigment. In all of the specimens sectioned numerous pigment granules have escaped from the cirri and at various places form small accumulations, but whether this is a normal process it is impossible to say. This secretion renders it also impossible to determine their innervation, a difficulty that is increased by the small calibre of the contained canal which in preserved specimens is too narrow to permit the entry of blood corpuscles.

The cirrus-bearing section of the digestive tract passes abruptly into the succeeding region, the junction in every case being guarded by a distinct fold which thus appears to be a permanent structure. At first the buccal-pharyngeal walls are almost smooth and the epithelial lining, composed of cubical cells, is thin but opposite the mid section of the brain the lumen narrows, becoming trefoil shaped in section, and numerous small transverse folds have developed which now are of greater thickness. This condition of affairs continues with slight modifications to the region of the ventral salivary glands where the canal becomes increasingly narrower and the corrugations more pronounced. As Plate 5, fig. 6, shows a clearly defined fold is present at the junction of the pharynx and stomach.

Throughout its entire extent the walls of the pharynx are thick and are composed internally of heavy circular muscles to which are attached numerous radiating bands inserted on the other hand to the body wall. All signs of a radula are absent and appearances suggest that this species like *Drepanomenia rampyrella* subsists on some delicate organism, such as the sea pens, whose juices are extracted by powerful sucking movements of the pharynx.

Two ventral salivary glands are present in the form of small tubular outgrowths opening on the underside of the pharynx about opposite the level of the hinder border of the brain. The cells are small but are filled with an abundant secretion, indicating that though these organs are diminutive they are functionally active.

As indicated (Plate 5, fig. 6), a dorsal coecum is but slightly developed, and the intestine from its junction with the pharynx to the cloaca is of uniform size and character, and is pouched in regular and characteristic fashion. Its walls are composed of high club-shaped cells in which the small nuclei are basally situated while the remaining portions are filled with large droplets of some secretion unaffected by haematoxylin. Immediately beneath the gonad the cells are much reduced in size, and are possessed of little if any glandular activity but bear a heavy coat of cilia. Near the anterior end of the coelomoducts the digestive canal narrows abruptly (Plate 6, fig. 1) to form a small canal which arising near the ventral side of the animal makes its way dorsally on the under side of the pericardium (Plate 24, fig. 5) to open into the cloaca. The cells composing it are essentially the same as those lining the intestine beneath the gonad.

The hermaphrodite gland extends forward as far as the posterior limits of the pharynx or slightly beyond (Plate 24, fig. 4) and in a sexually mature animal contains ripe sex products throughout its entire extent. These originate in the usual fashion and are in no wise peculiar save that the fully developed eggs are unusually large, measuring 0.176 mm. Clearly defined tubes lead from the gonad into the pericardium, which in the specimen represented in Plate 6, fig. 1, contains both ova and sperms. The antero-ventral pericardial wall is ciliated and elsewhere cilia appear to be present though the true condition of affairs is masked by the abundance of precipitated secretion.

From the posterior end of the pericardium the coelomoducts arise as relatively narrow canals lined with almost cubical cells bearing a coat of cilia similar to those of the pericardium. Coursing downward and forward they gradually increase in size and the walls, retaining their ciliated coat, develop several folds before they unite with the limbs of the huge gland a short distance behind their anterior boundaries. At about one fourth of the distance from the pericardial opening to its outlet into the shell gland each tube originates what probably functions as a seminal vesicle (Plate 6, fig. 1). In calibre and histological features each is similar to the neighboring parent canal with the exception of the distal extremity which forms an enlarged, almost globular dilation. From beginning to end the *vesicula seminales* contain spermatozoa in most cases attached by their heads to the epithelial lining. Distal to the openings into the vesicles the coelomoducts contain small quantities of spermatozoa, unattached.

At the junction of the dorsal and ventral limbs of the coelomoduct on each

side a very large seminal receptacle is attached. Each originates as a slender duct, which pursues a tortuous course anteriorly, and opens on the lateral or latero-ventral surface of a vesicular enlargement with folded walls. The cells composing the duct are histologically essentially the same as those of the seminal vesicles save that they are of almost twice the height. Those of the dilation are likewise columnar and contain a glandular secretion which escapes distally in the form of moderately staining droplets. In addition to this secretion the receptacle contains numbers of sperms some of which are deeply imbedded in the walls. Whether these last named structures are intact or not it is impossible to state; they show no clear signs of disintegration.

The Y-shaped ventral section, or shell gland, is of large size and its walls, developed into many irregular folds, are unusually thin. Distal to the median, undivided section the cells of the epithelial lining are chiefly glandular, hemmed in by slender supporting cells, and are filled with a violet colored vacuolated secretion in haematoxylin preparations. In the adjacent undivided region this type of cell is replaced by another of much greater length (Plate 24, fig. 2) in which the secretion is more vacuolated and stains less deeply. Associated with these are comparatively few elongated cells filled with a dark, coarsely granular secretion and very many containing in each a granule of a dark brownish color. These occur in the anterior half of the undivided part of the shell gland; from it the transition to the posterior half is very abrupt, especially dorsally where the cells become higher and are filled almost completely with a substance of varying character, depending probably on the nearness of the egg-laying season. In one specimen with sex products in the pericardial cavity these cells near their free surface contain one or two large spherical dark blue or violet globules, while the remaining cytoplasm, is packed with an almost homogeneous mass. Ventrally the secretion is more granular and the more distal products are yellowish brown in color. In another specimen treated in identically the same manner these products have much the same appearance, but stain slightly. The lumen of the shell gland is spacious and opens in the dorsal part of the cloacal cavity near the anus.

Opening by a wide pore posterior to the reproductive outlet is a large diverticulum of unknown function (Plate 6, fig. 1). Its walls are somewhat folded and are reinforced by a thick muscular coat (Plate 24, fig. 2). The epithelial lining consists of columnar cells of average height covered externally with a thin, sharply defined cuticular layer. Among the cells of this character are others, fairly numerous, very slender, with dense elongate nuclei, that in especially

favorable material may be seen to terminate proximally in fibres passing into the muscle layer. Distally they attach to the bottom of minute depressions in the cuticle and therefore probably are sensory elements.

In two specimens the cloacal cavity has been widened greatly, completely exposing the anus and the openings of the shell gland and the more ventral diverticulum. This last named organ has been almost completely everted. These individuals appear in all respects to be normal.

With the stains employed the nervous system is not sharply differentiated from the surrounding tissue, and accordingly but little has been determined save that relating to the larger ganglia and nerves. As may be seen (Plate 5, fig. 6), the brain holds the usual position and gives rise to the customary nerves distributed to the atrium and the body wall and more posteriorly to the pedal, lateral, and labio-buccal connectives. The pedal cords are considerably enlarged at their anterior ends, while the lateral show scarcely any modification. Pedal commissures and latero-pedal connectives occur at fairly regular intervals throughout the entire length of the animal. The labio-buccal ganglia are located at the sides of the pharynx a short distance behind the level of the salivary glands, and are united by at least one ventral commissure. In the posterior end of the body the relations of ganglia and nerves are not especially clear, but the pedal cords appear to end in small enlargements, united with the termination of the lateral ganglia by one or two slightly enlarged connectives. As usual nerves pass into the hinder part of the animal from the ends of the lateral ganglia which are united by the usual suprarectal commissure.

GENERAL CONSIDERATIONS.

If unanimity of opinion be any criterion whereby we may judge the correctness of a theory it must be admitted that we are yet a long way from the solution of the origin of the Mollusca, for scarcely any two investigators hold identically the same views. In their development or in their adult organization many of the members of the phylum exhibit features which are the close counterpart of others in the flatworms and annelids and it may well be that, generally speaking, those students are correct who hold to the idea that all have descended from a common ancestor, though the details of the process are most obscure. Narrowing down the problem to the Solenogastres there are few who dissent from the opinion that they are true molluscs, though it cannot be said their position within the group is definitely established. However it is becoming

increasingly evident that they possess more characters in common with the Chitons than with the other classes, and these characters, interpreted in the light of community of descent of the two groups, are more readily understood than from any other viewpoint.

It is little more than waste effort at the present time to attempt to reconstruct the external characters of the ancestral Solenogastre, for it is generally agreed that the present day species, worm-like in form and without shell or well-developed foot, are highly modified in these respects. The aggravatingly few facts of their embryology are also without much value for the solution of the problem. As the matter now stands there is no positive evidence that they ever had a shell, but in view of the fact that these animals show a close resemblance to the Chitons in several other respects it is not unreasonable to believe that one was formerly present. It must be admitted that Pruvot's figure and description regarding the shell in the larvae of *Dondersia banyulensis* are very indefinite, and have led some authors to claim that the seven valves of the dorsal side are in reality greatly enlarged scales. There are some evidences that such is indeed the case in the young of *Holomenia gravida*, at all events the plates do not develop exactly as does the Chiton shell. It is possible that we have here the confirmation of Blumrich's theory that the original shell arose by the excessive development of flattened spines along the dorsal surface of the animal.

It is a significant fact that the mantle of the Solenogastres has no counterpart save in the Chitons. In the least modified condition it consists primarily of a single layer of epithelial cells overlaid by a cuticular covering often of enormous thickness. Those probably responsible for the formation of the cuticle, and of pigment when such is present, are comparatively simple, unmodified, more or less columnar cells. At frequent intervals throughout the layer spicule-matrix cells arise and develop a single stratum of spines, or several layers imbedded in the cuticle. In their mode of origin the spines of the Solenogastres are essentially similar to those of the Chitons (see p. 29). Thiele declares that the Solenogastre spicule is produced from one matrix cell, but this method is certainly not frequent, and Plate states that it is rare among the Chitons. Wiren reports that in Chaetoderma there is one basal cell and three smaller ones encompassing the young spine. Hubrecht discovered that in *Proneomenia sluiteri* the base of each spicule is grasped by a considerable number of matrix cells, and as the spine is carried outward by the continued growth of the cuticle they continue to retain their attachment for a long period. Pruvot ('90) finds in a few species that during the early development of the spicule four or five cells

are in contact with it, and the attachment may persist for a considerable period. In *Pronomenia hawaiiensis* and a number of other species I have found that there is one basal cell, apparently responsible for the formation of calcareous material, surrounded by seven or eight smaller cells attached also to the base of the spine and perhaps responsible for the formation of the cuticular sheath. This last named mode of formation is almost the exact duplicate of the most common method of spine development of the Chitons (Plate, 1901, p. 372).

Among the Chitons the matrix cells retain their connection with the spicule as long as it exists. In the Chaetodermatidae, and in those Neomeniina with a single layer of spines, there is a tendency to follow this primitive method. The same is true, though in some cases to a more limited extent, in a few species with thick cuticle and several layers of spicules, notably *P. hawaiiensis* and *Strophomenia scandens*.

The balloon-shaped papillae developed from the hypodermis and in a fully developed condition extending to the free surface of the cuticle are of problematical significance. It has been suggested (Kowalevsky & Marion, Wiren) that they may be spicule-matrix cells that have assumed some new function after the formation of the spine; but the fact that in *P. hawaiiensis* the matrix cells retain their attachment, at least in part, as long as the spine is imbedded in the cuticle, precludes such a possibility. In Alexandromenia there are many times more spines than papillae. Heuscher on the other hand describes their origin as simple outgrowths of the hypodermis. Regarding their homologue in the Chitons nothing may be claimed definitely. They may correspond to the packets or papillae (Plate) or, with a greater degree of probability, to the aesthetes as several authors have claimed.

That a foot of much larger size existed in the ancestral Solenogastre and that the ventral groove of the Neomeniidae does not "represent the first stage in the formation of that pedal surface of the body which is seen in the lowest mollusca" (Gegenbaur) is indicated by a number of facts. In the first place although no external trace of a foot exists in the Chaetodermatidae there is a space along the mid ventral line between the longitudinal somatic muscles which are thicker here than elsewhere, and in Limifossor this same space is occupied by a sinus exactly similar to the pedal sinus of the Neomeniidae. In Limifossor the pedal sinus anteriorly penetrates a clearly defined septum and communicates with the head cavity as in the Chitons. It is much more reasonable to consider that the pedal sinus is the remnant of the foot of the ancestral Solenogastre than that it is the first sign of the appearance of a definite creeping surface.

In the Neomeniina there is the same cleft in the ventral musculature, thickened as in the Chaetodermatina, and the foot is present as a small fold extending along the mid ventral line. Anteriorly it affords an outlet for the enormously developed anterior pedal gland which in position and development as far as this has been traced (see Heath '05), is homologous with the pedal gland of young Chitons. The remainder of the foot is supplied with the posterior pedal glands which are present in a diffuse condition in the Chiton foot.

In the Solenogastres there are no eyes, tentacles and even the proboscis or snout of the Chitons is believed generally to have no homologue in the group. Concerning this last named organ however Thiele claims (and in this he is followed by Nierstrasz and Pelseneer) that it is present, though in a highly modified condition and I am strongly convinced of the force of his argument. In the first place it is a well-known fact that the first section of the alimentary canal in the Neomeniina contains the atrial ridges (Mundleisten) and the enclosed cirrose area, all innervated by fibres originated directly by the cerebral ganglia. In *Rhopalomenia aglaopheniae, Dinomenia hubrechti*, etc., and I have found the same state of affairs in *Driomenia pacifica*, this portion of the canal exists in the form of a depression in front of the mouth, and is separated from it by a narrow bridge of spicule bearing cells continuous with the general covering of the body. Owing chiefly to its innervation Thiele considers that this "sensibles Atrium" is the homologue of the Chiton snout which is now withdrawn into a depression. Where this atrium is a direct part of the digestive tube the true mouth has been drawn into the body and is located immediately behind the most posterior atrial ridge. It now becomes an interesting fact that in the Chiton development the mouth at first is posterior to the snout and but slowly takes up its final central position (cf. Heath '99). It lends support to the belief that in these molluscs with isolated atrial cavity the position of these organs does not represent a highly modified condition but a relatively primitive state of affairs.

In the Chaetodermatidae the nerves which originate from the anterior surface of the brain pass at once into the huge, compact ganglionic bodies homologous, I believe, with the more diffuse nerve masses in contact with the bases of the cirri and buccal sensory ridges in the Neomeniidae. From these a relatively enormous number of fibres pass into the Mundschild or buccal plate, just as the cirri and ridges are innervated by nerves from the neighboring ganglia. There is thus little doubt that the buccal plate and sensory atrium are homologous and if the above line of reasoning be correct, they are the homologue also of the Chiton snout, which is likewise innervated by nerves from the cerebral ganglia.

Regarding the mantle cavity I believe that it as truly exists in the Solenogastres as in the Chitons or prosobranchs, for example. The sole reason for considering that the so-called branchial or cloacal cavity is a secondary modification appears to have chiefly originated with Thiele who claims that the branchial lamellae of various neomenians are highly developed rectal folds and accordingly the branchial cavity is nothing more than a greatly expanded rectum. The same is true of the Chaetodermatidae, for the plume-like respiratory organs are said to have been developed from similar rectal folds, and accordingly their remarkable resemblance to true ctenidia is of no especial significance. Furthermore the fact that the nephridia open into this space is likewise of no importance for it is of coenogenetic origin.

Regarding the branchial plates of the Neomeniina, they certainly have every appearance of being merely folds of the walls of the branchial cavity, but that they are closely related phylogenetically to the respiratory organs of the Chaetodermatidae is an entirely different matter and one most difficult to substantiate. On the other hand it seems to me that the gills of this last named family are not clearly homologous with the neomenian respiratory organs. In a former paper I have called attention to the fact that in gross and microscopic appearance, blood supply, and innervation they are practically identical to the Chiton gill. Such an idea brings us without violence to the belief that in the original ancestor of the Solenogastres and Chitons there was a true mantle cavity containing at least two ctenidia, the separate outlets of the urogenital system and possibly an osphradium though such an organ may well have been in a diffuse condition as in some of the modern lamellibranchs. Accordingly the connection between the pedal furrow and the mantle cavity is not secondary but primitive and similar in its broader features to what is found in the Chitons. The polybranchiate character of this last named group yet remains a puzzle for as I have pointed out ('05) there is nothing in the development of these organs to indicate if it be primitive or not.

While several fundamental differences between the circulatory systems of the Solenogastres and the Chitons have been found to exist these may be explained to some extent on the supposition that originally the foot was of larger size, and in any event they do not outweigh several remarkable resemblances. In both the pericardium is dorsal, posterior, and communicates with the exterior with paired ducts. In present day species it contains the heart, a simple tubular organ or differentiated into a ventricle and single auricle, which may originally have been paired as Wiren has ingeniously suggested. From the anterior end

of the heart the aorta arises and passing along the dorsal side of the gonad, that it supplies in Chiton-like fashion, it reaches the head cavity. In the great majority of species this last named organ is not clearly defined, but in Limifossor it is separated from the visceral cavity by a connective-tissue septum as clearly defined as in the Chitons and having essentially the same relations. Within the head sinus the blood makes its way by irregular channels into the visceral cavity and passes backward. In Limifossor the septum is perforated ventral to the intestine and through this the blood makes its way into the ventral sinus. A special visceral artery or sinus is lacking within the group, its function being taken by the general visceral cavity and ventral sinus. This last named space communicates freely at many points with the visceral cavity and posteriorly both unite and the combined vessel makes its way to the ctenidia and from thence into the heart.

Hansen years ago noted the presence of crystals in the coelomoducts of Chaetoderma, and considered it possible that they may function as kidneys. From much more extensive studies Wiren has taken the same position, showing the close similarity of the tissue to that of the Chiton kidney. Another fact of the greatest importance is that in *Chaetoderma crudita* for example, where the sexes are separate *the nephridia of the male are exactly the same as those of the female.* If the coelomoducts here act in the capacity of shell, mucous or other glands intimately connected with the egg-laying process it is reasonable to suppose that it would be more highly developed in the female than in the male. Since it is not it becomes much more probable that the resemblance of the cells of the duct to those of the Chiton kidney is not accidental, but that they are true excretory elements and the ducts therefore have retained the excretory function derived from the ancestral form.

Stating the matter in another way it appears that the coelomoducts are, from the standpoint of both structure and function, of a more primitive character in the Chaetodermatina than in the Neomeniina. In the latter family the ducts have assumed an important rôle in the storage of sperms, or in the development of envelopes for ova and perhaps other processes connected with egg-laying, so that the original function of excretion is effectually masked, if it exist at all. In the Chitons the kidneys become active excretory organs long before any trace of the gonad or its ducts appear, and if these tubes in the Neomeniina act as kidneys they likewise would probably assume their duties at an early stage. In *Dorymenia acuta*, however, there are no signs of such activity in individuals 14 mm. in length. The reproductive glands are present, though in a very im-

mature condition, and the coelomoducts, having the form of canals of about equal calibre throughout, lead in the usual fashion to the exterior. Their lining epithelium is composed of low, usually cubical cells, non-vacuolated, without any traces of concrements or crystals, and indications of any glandular activity whatsoever are totally absent. I am therefore strongly of the belief that the coelomoducts in the Neomeniina are solely concerned in the reproductive process.

Granted that the section of the alimentary canal, including the cirrose area and the buccal sensory ridges, is the homologue of the Chiton snout, or at all events a comparatively late formation, the remaining portions are decidedly Chiton-like. In most species there are both dorsal and ventral salivary glands which show a surprising amount of variation, ranging from scarcely distinguishable bodies to others of great size and a high degree of complexity. As in the case of the Chitons the dorsal set typically opens through the dorsal buccal wall while the outlets of the ventral pair are in the neighborhood of the radula.

The radula, in a number of species is lacking, and in several others it is in a degenerate state, being reduced to a peg-like body (Chaetoderma) or to a very few teeth which are reported to lack a basement membrane. On the other hand there are species, such as Kruppomenia (Nierstrasz, '05) and Limifossor (Heath, '05) which have typical radulae, as regards location and component parts. Odontoblasts, cells which form the basement membrane, and enamel cells are all present, and the resemblance to the radulae of other molluscs, as figured by Rossler for example, is surprisingly complete.

The fate of the subradular organ appears to depend closely upon that of the radula. In every case that has come under my observation it is lacking or is reduced to the merest rudiment when the radula has disappeared, and in some species it is in a highly degenerate state when the radula is in a similar condition. It is to be noted that the nerve supply to this organ may be a much more conservative set of organs, persisting in *Strophlomenia scandens*, for example, after the organ has ceased to exist as a well-defined structure.

The limits of the posterior end of the pharynx and consequently of the anterior end of the oesophagus are not sharply defined histologically and in the absence of embryological evidence they remain problematical. In fact the oesophagus is sometimes disregarded as a definite section of the gut or is included in the description of the pharynx. In some species it appears to be bounded anteriorly by a circular fold and posteriorly it is probably terminated at the commencement of the stomach-intestine.

The intestine is differentiated into a well-defined stomach and intestine,

in the Chaetodermatina and as is well known this latter organ is practically straight. In the Neomeniina it is unique in possessing an anterior dorsal coecum that extends forward to the neighborhood of the brain; and the liver is not sharply differentiated from the gut. The opening of the rectum into the mantle cavity and its relation to the nervous system may be derived without serious difficulty from a condition similar to that of the Polyplacophora.

In their broader features the nervous systems of the Solenogastres are all reducible to one type, as Thiele and Nierstrasz maintain. In practically every species described in the present paper, the brain is bilobed and always connects with the pedal, lateral, and labio-buccal systems. In the Neomeniina three pairs of nerves, often associated with small ganglia of problematical homology, are distributed to the anterior end of the body and attach to numerous ganglionic masses applied to the walls of the atrial cavity. In the Chaetodermatina a larger number of nerve bundles arise from the anterior surface of the brain and connect with great ganglionic bodies often almost enveloping the brain. From these ganglia branches pass to the buccal plate. Judging from its innervation the atrial cavity is thus the homologue of the buccal sensory plate (Mundschild), and both are homologous with the Chiton snout. Accordingly the ganglia attached to the brain are the counterpart of those applied to the bases of the cirri. Thiele has called attention to the inappropriateness of the term "buccal" in speaking of these ganglia, and accordingly the term precerebral may be used.

In a primitive condition the lateral, pedal, and labio-buccal connectives probably arose as independent trunks, but in many species they are more or less fused for some distance. The ventral and pedal ganglia are usually enlarged at the point of union with the connectives, and may originate nerves distributed to the walls of the pedal-gland outlet, atrium and to some extent of the body. Commissures at fairly regular intervals attach the pedal ganglia and may develop small branches distributed to the tissue in the vicinity of the ventral fold or foot. About the same number of connectives unite the pedal and lateral ganglia, and likewise give rise to small offshoots passing into the somatic musculature. Other nerves, with seemingly the same destination, form from the upper surface of the lateral ganglia and course dorsally. In the posterior end of the body the lateral ganglia usually enlarge and invariably are united by a suprarectal commissure. From these enlargements branches pass to the body and cloacal walls, and from the commissure in the mid line a fibre arises, in some species, that is distributed to the dorso-terminal sense organ. The pedal ganglia may gradually diminish in size posteriorly or become attached

to the lateral by means of one or more enlarged connectives; and in a few species a posterior commissure may complete a circumrectal ring. In the Neomeniina fibres from the dorso-posterior enlargements have been traced into the tissue surrounding the shell gland, into the body wall and in *Strophomenia ophidiana* delicate nerves have been traced from the enlargements of the lateral ganglia into the heart. In the Chaetodermatidae practically all of the nerves innervating the posterior end of the body spring from the suprarectal commissure or in close proximity to it. In Limifossor the gills are innervated by two pairs of branches from the commissure and in *Chaetoderma attenuata*, *C. erudita* and probably others the same is true. I have been unable to find a circumrectal ring described by Wiren ('92).

The labio-buccal system has been examined critically in a few species only, yet the few facts gleaned indicate that in a typical condition it is not unlike what is found in the Chitons. For many years the so-called buccal ring has been known both in the Chaetodermatina and in the Neomeniina, consisting of two connectives coursing along the sides of the pharynx and uniting with two ganglia in the neighborhood of the radula or the outlet of the ventral salivary glands. These ganglia, which I have termed labio-buccal, are in turn connected by means of a ventral commissure, which in the genus Chaetoderma bears two small ganglia. In *Proneomenia hawaiiensis* there is a very distinct subradular organ, consisting of two clearly defined circular patches of high epithelial cells on each side of the mid line in front of the radula. In close proximity to these are small ganglia, united by a commissure, and on the other hand joined with the labio-buccal ganglia by connectives. In addition there is a dorsal commissure uniting the labio-buccal connectives and possibly another ventral one. These same elements in a more compact form, exist in *Strophomenia scandens*. In the genus Chaetoderma I have recently shown that in front of the radula connectives attached to the labio-buccal connectives, and, after giving off nerves which pass directly to modified epithelial patch in the pharynx, are united with a single ganglionic mass. In Limifossor there is in addition to the well-known commissure a dorsal one and probably a second ventral one. In *Dorymenia acuta* there are two dorsal commissures and two ventral, one of which bears a pair of small ganglia. The radula is certainly in a degenerate condition in several species of Solenogastres; it has disappeared in others and the same extremes exist in the case of the subradular organ. Consequently it is not remarkable that the system of ganglia and nerves associated with these sensory areas exhibit marked differences in the various species.

Comparing the labio-buccal systems of *Proneomenia hawaiiensis* and a Chiton (*Trachydermon raymondi*) it is seen that in the Solenogastres the connectives attaching the subradular, buccal, and labial systems with the brain are of great length; in the Chitons they are very short. In the Chitons the buccal ganglia are clearly differentiated; in the Solenogastres they are fused with the labial. These homologies have been treated in another paper (Heath '05), and offer, so far as I can see, no serious difficulty.

Nerves from the labio-buccal ganglia have been seen in both of the divisions of the Solenogastres to pass into the pharynx which they doubtless innervate. In *Chaetoderma erudita* they have been traced as far as the end of the pharynx. In the Chaetodermatidae practically all of the nerves innervating the posterior end of the body arise on the suprarectal commissure or in close proximity to it. In Limifossor the gills are innervated by two pairs of branches from the commissure and in *Chaetoderma attenuata*, *C. erudita* and probably others the same is true.

While the facts discussed in the foregoing paragraphs appear to justify the conclusion that the Solenogastres are most closely related to the Chitons, they do not as certainly settle the question as to which group has retained the greater number of ancestral characters. The condition of the coelom in the first named division appears to be very primitive and probably palingenetic; and, generally speaking, the musculature is more simple, and this is true to some extent of the digestive tract, though these may have been secondarily modified. The absence of a shell and well-developed foot, the relatively simple condition of the circulatory apparatus, the concentration of the nervous system, and, in the Neomeniina, the high degree of development of the coelomoducts point more clearly to modifications of a more primitive type. Without entering into further detail it would appear that, with the data now available, the Chitons are to be considered the more primitive, in fact the most primitive of all molluscs.

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EXPLANATION OF THE PLATES.

a anus.
aor aorta.
ap anterior pedal gland
b brain.
bc buccal commissure.
bg labio-buccal ganglion.
br gill.
brn nerves to gills.
c intestinal cœcum.
cl cloacal chamber.
co cloacal cœcum.
cp coelomoduct.
da dorsal aorta.
dsg dorsal salivary gland.
fo buccal plate.
gl glands of pharynx.
gon gonad.
ht heart.
int intestine.
lb labio-buccal connective
liv liver.
m mouth.
n nerve to buccal plate.
oc œsophagus.
pc pedal ganglion.
peg precerebral ganglion
pcm pericardium.
ph pharynx.
pl lateral ganglion.
ps pedal sinus.
r radula.
re seminal receptacle
rs radular support.
s anterior vertical septum
sc subradular commissure
sg ventral salivary gland
sgl shell gland.
sn subradular ganglion.
so sense organ.
sp spicule.
sr dorsal gill retractor.
sro subradular organ.
sto stomach.
sv seminal vesicle.
vr ventral gill retractor
vs ventral diaphragm.

PLATE 1.

PLATE 1

Fig. 1. Strophomenia farrmeu. × 3.
Fig. 2. Strophomenia ophidiana. × 3.
Fig. 3. Strophomenia spinosa. × 5.
Fig. 4. Herpomenia platypoda. × 10.
Fig. 5. Strophomenia triangularis. × 8.

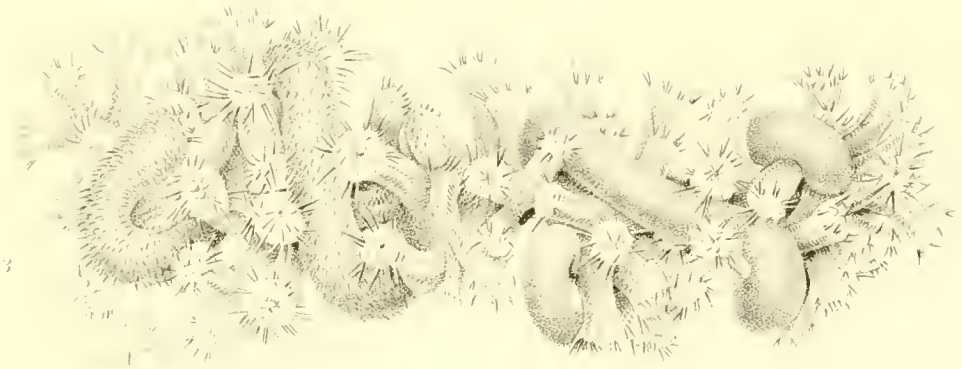
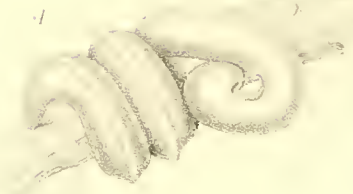


PLATE 2.

PLATE 2.

Fig. 1. Strophomenia scandens. × 4.
Fig. 2. Drepanomenia vampyrella. × 7.
Fig. 3. Chaetoderma hawaiiensis. × 8.
Fig. 4. Lophomenia spiralis. × 7.
Fig. 5. Alexandromenia agassizi. × 4.
Fig. 6. Limifossor fratula. × 5.



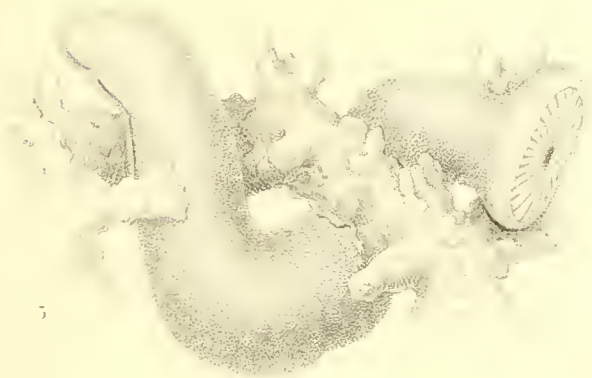


PLATE 3.

PLATE 3.

Fig. 1. Halomenia gravida. × 6.
Fig. 2. Strophomenia farcimen; unusually thick specimen. × 7.
Fig. 3. Alexandromenia valida. × 3.
Fig. 4. Ichthyomenia porosa. × 9.
Fig. 5. Reconstruction of posterior end of Halomenia gravida.
Fig. 6. Halomenia gravida. Anterior end. × 10.
Fig. 7. Chaetoderma japonica. × 4.
Fig. 8. Head of Chaetoderma japonica. × 16.
Fig. 9. Dondersia californica × 9.
Fig. 10. Proneomenia hawaiiensis. × 2.
Fig. 11. Dorymenia acuta. × 3.

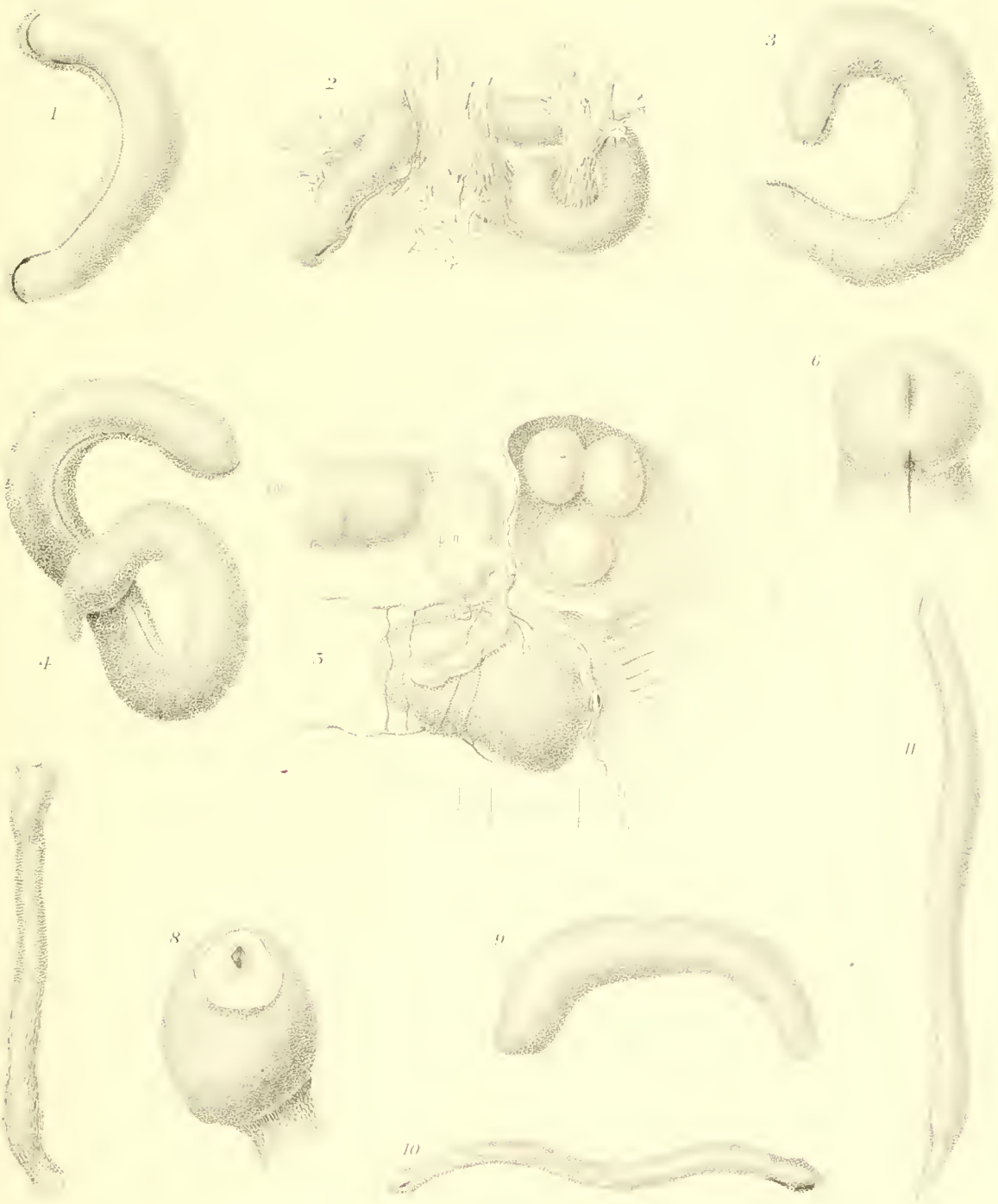

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PLATE 4.

PLATE 4.

Fig. 1. Chaetoderma nanula. × 7.
Fig. 2. Chaetoderma scabra. × 7.
Fig. 3. Chaetoderma attenuata. Living specimen. × 2.
Fig. 4. Chaetoderma montereyensis. × 1.3.
Fig. 5. Chaetoderma robusta. × 1.3.
Fig. 6. Chaetoderma californica. × 3.
Fig. 7. Chaetoderma argentea. Living specimen. × 2.5.
Fig. 8. Chaetoderma montereyensis. × 2.
Fig. 9. Chaetoderma erudita. Living specimen. × 2.
Fig. 10. Chaetoderma attenuata, front and side views. Living specimen. × 10.
Fig. 11. Chaetoderma erudita. × 15.
Fig. 12. Chaetoderma nanula. × 15.
Fig. 13. Limifossor fratula. × 13.
Fig. 14. Chaetoderma montereyensis. × 15.
Fig. 15. Dondersia californica. Anterior end. × 22.
Fig. 16. Chaetoderma scabra. × 15.
Fig. 17. Chaetoderma montereyensis. × 10.
Fig. 18. Dondersia californica. Posterior end. × 22.
Fig. 19. Chaetoderma robusta. × 8.

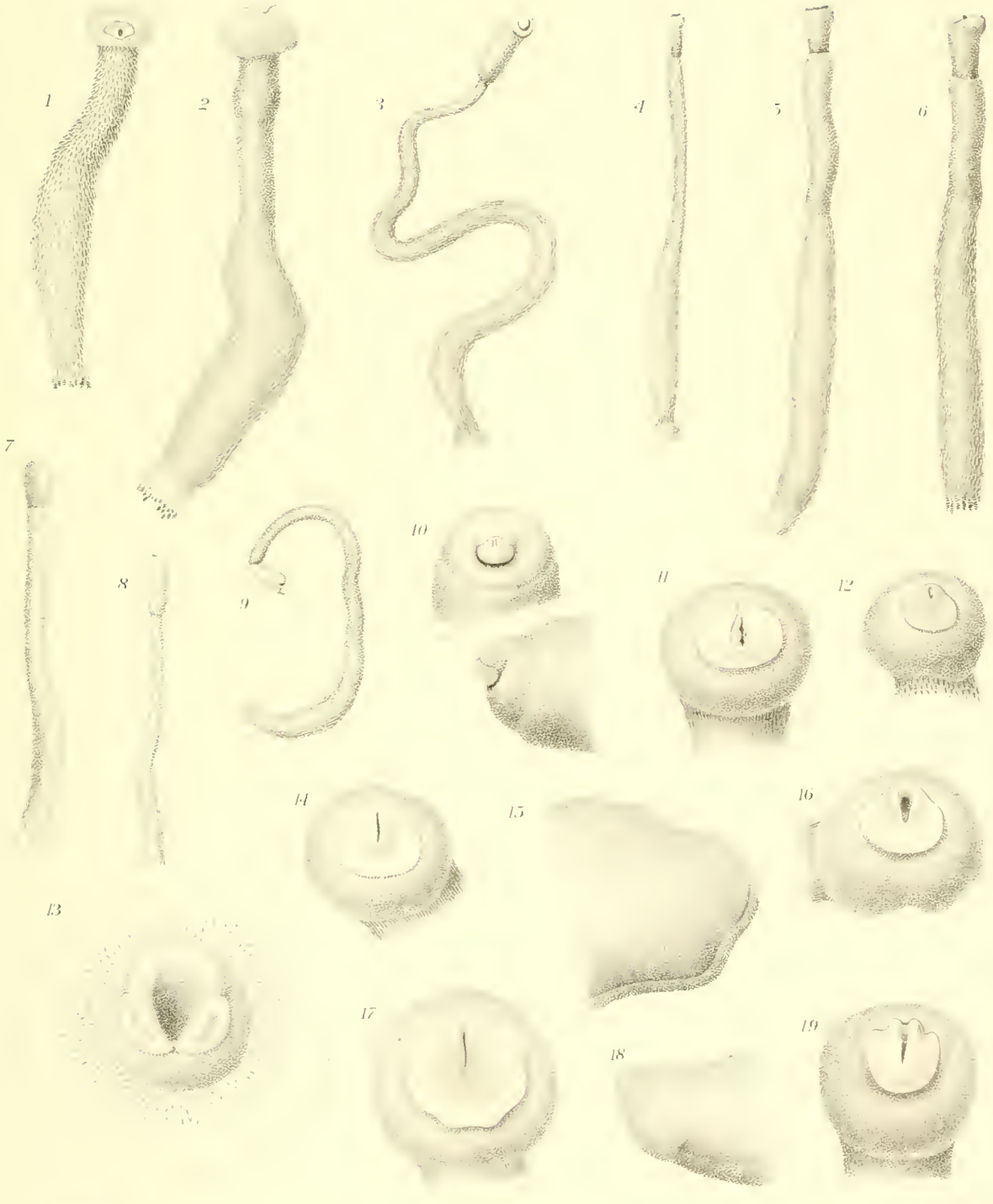
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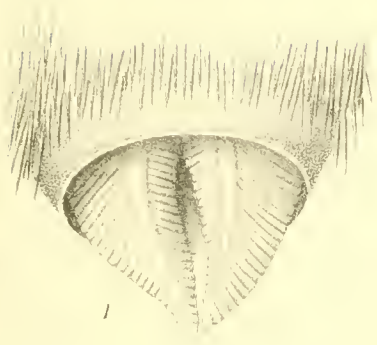
PLATE 5

PLATE 5.

Fig. 1. Posterior end of Chaetoderma attenuata, living specimen.
Fig. 2. Reconstruction of anterior end of Proneomenia hawaiiensis.
Fig. 3. Same of Halomenia gravida.
Fig. 4. Same of Dondersia californica
Fig. 5. Posterior end of Alexandromenia agassizi.
Fig. 6. Anterior end of Ichthyomenia porosa.



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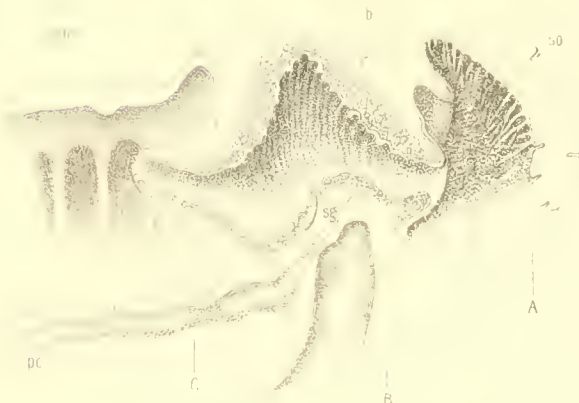

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PLATE 6.

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Fig. 1. Reconstruction of posterior end of Ichthyomenia porosa.

Fig. 2. Same of Dondersia californica.

Fig. 3. Same of Drepanomenia vampyrella.

Fig. 4 Same of Dorymenia acuta.

Fig. 5. Same of anterior end of Lophomenia spiralis.

Fig. 6. Junction of pharynx and stomach-intestine in Strophomenia scandens, showing opening of the ventral salivary gland and a portion of the labio-buccal system.

Fig. 7. Reconstruction of posterior end of Strophomenia scandens.

Fig. 8. Same of Chaetoderma hawaiiensis. dso dorso-terminal groove; gn suprarectal commissure; nd coelomoduct; rpo reno-pericardial opening.

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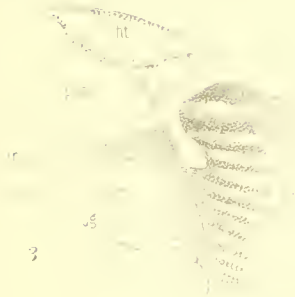

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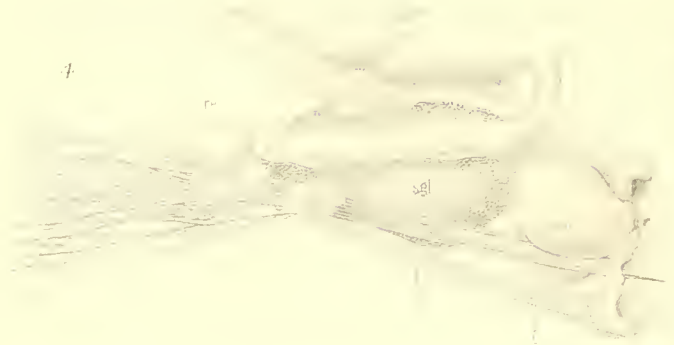

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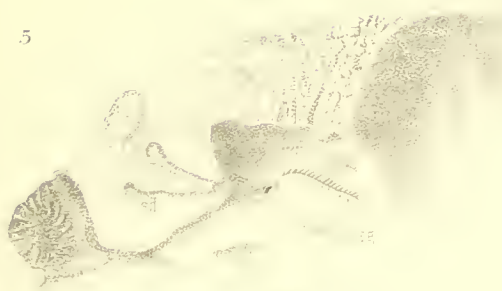

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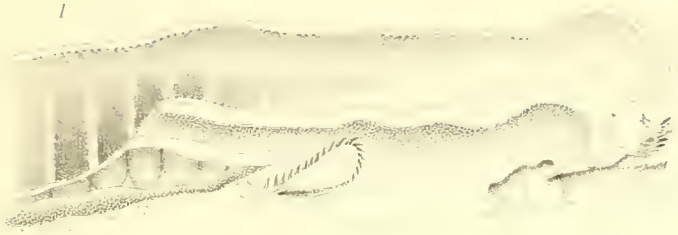
PLATE 7.

PLATE 7.

Fig. 1. Reconstruction of anterior end of Strophomenia farcimen.
Fig. 2. Same of anterior end of Chaetoderma hawaiiensis.
Fig. 3. Same of anterior end of Alexandromenia agassizi.
Fig. 4. Same of anterior end of Drepanomenia vampyrella.
Fig. 5. Same of posterior end of Alexandromenia agassizi.



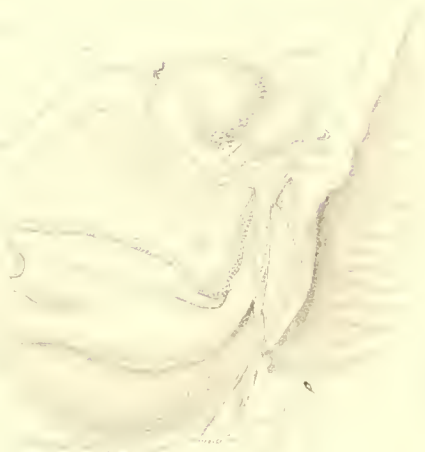


PLATE 8.

PLATE 8.

Fig. 1. Reconstruction of anterior end of Herpomenia platypoda.
Fig. 2. Same of anterior end of Strophomenia spinosa, small specimen.
Fig. 3. Same of posterior end of Herpomenia platypoda.
Fig. 4. Same of anterior end of Proneomenia insularis.
Fig. 5. Same of anterior end of Strophomenia ophidiana.
Fig. 6. Same of posterior end of Lophomenia spiralis.

PLATE 9.

PLATE 9.

Reconstruction of the posterior end of the body from transverse sections.

Fig. 1. Strophomenia ophidiana.
Fig. 2. Dorymenia acuta.
Fig. 3. Strophomenia triangularis.
Fig. 4. Strophomenia spinosa.
Fig. 5. Lophomenia spiralis.

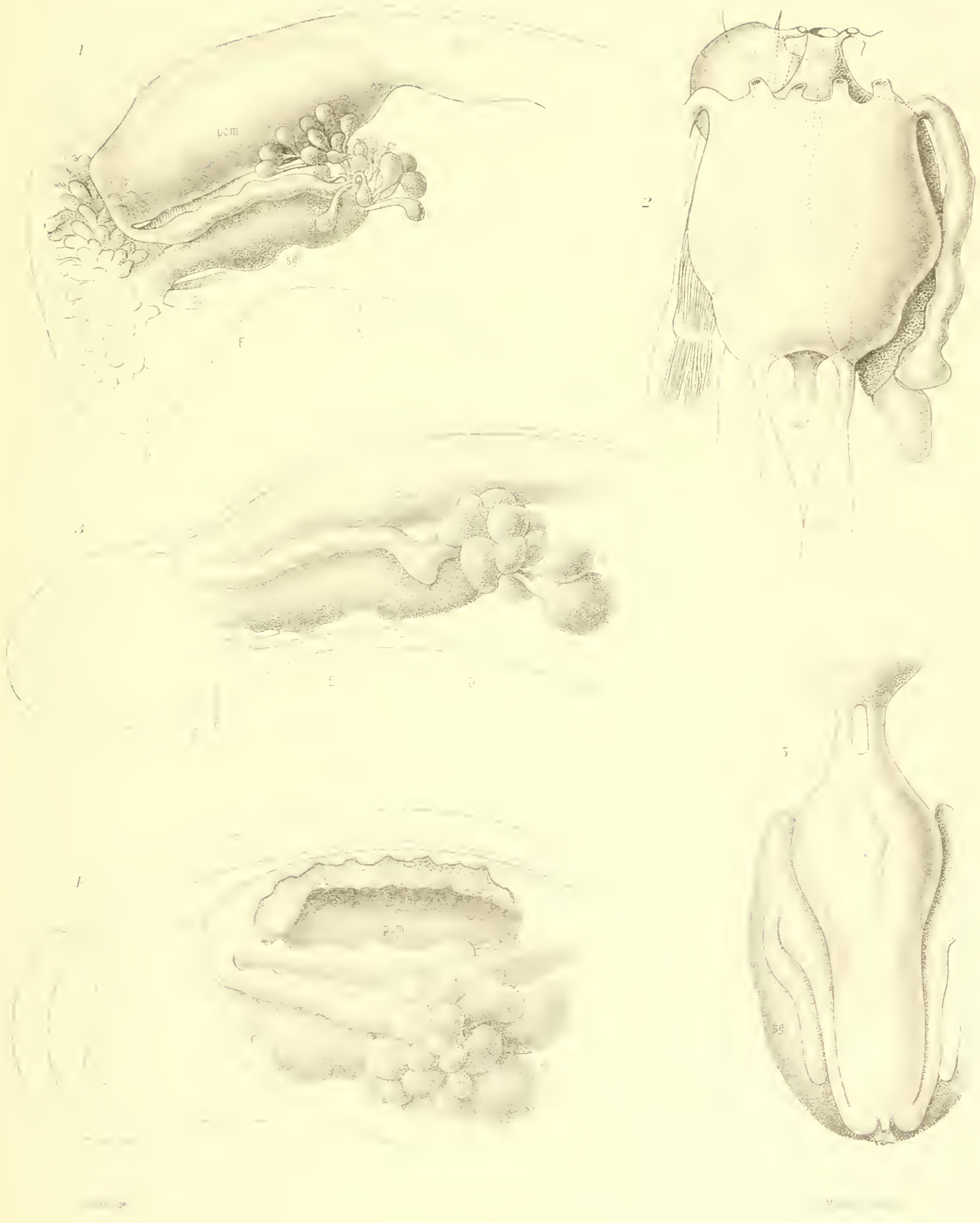

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PLATE 10.

PLATE 10.

Figs. 1–7, 9–10. Sections of Limifossor talpoideus; Fig. 8. Chaetoderma erudita.

Fig. 1. Side view, living specimen. × 5.
Fig. 2. Anterior end, living specimen, showing extremes of motion of frontal sense organ.
Fig. 3. Lateral view of organs of posterior end of body.
Fig. 4. Same of organs in anterior part of body.
Fig. 5. Diagram of radula and muscles that open and close the teeth.
Fig. 6. Section through dorsal sense organ. × 135.
Fig. 7. Lateral view of buccal mass, showing more important muscles that operate the radula and its supports.
Fig. 8. Brain and labio-buccal nervous system.
Fig. 9. Spicules from middle of body, front and side views. × 110.
Fig. 10. Dorsal view of radula and its supports; portion of dorsal pharyngeal wall removed.

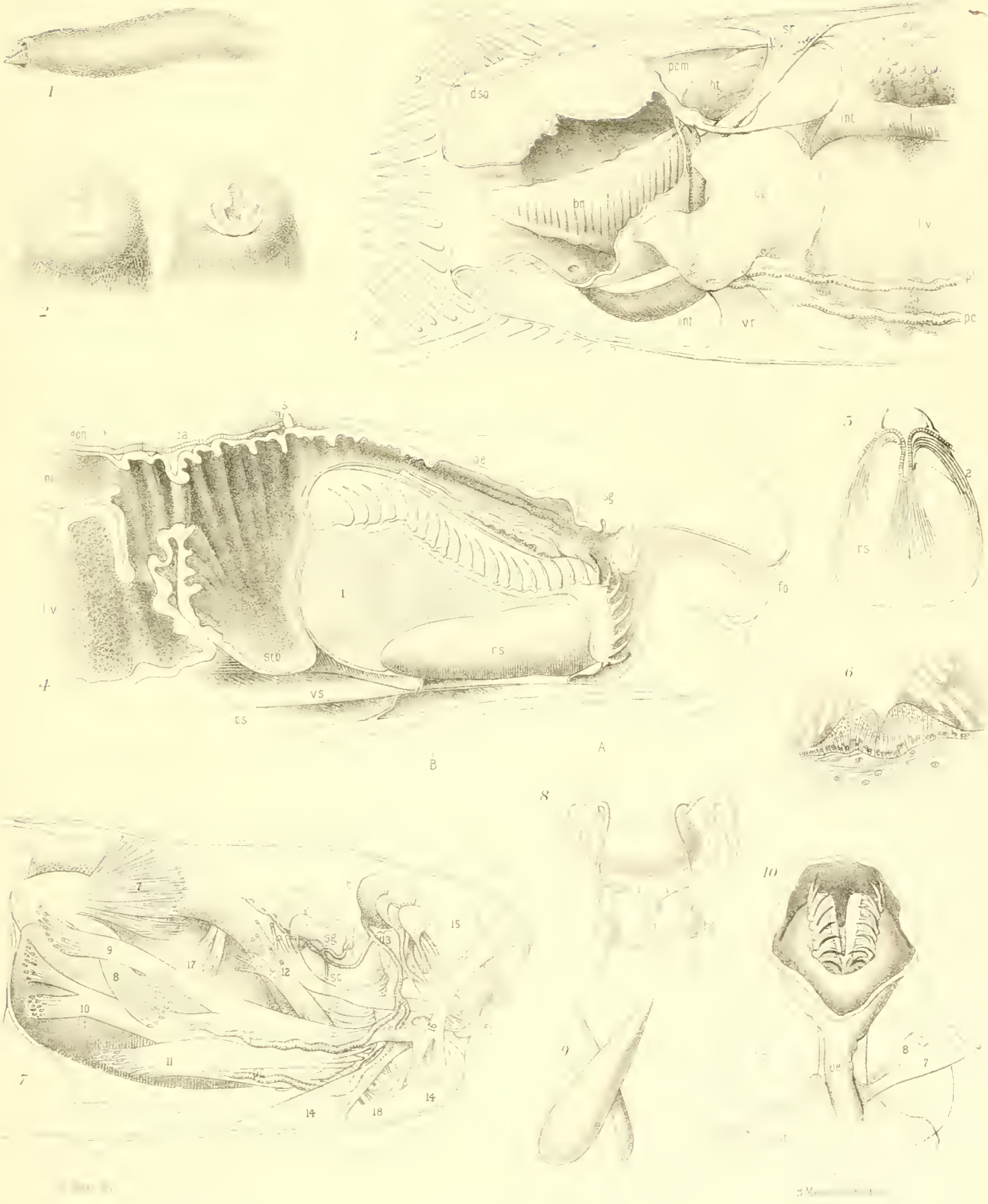
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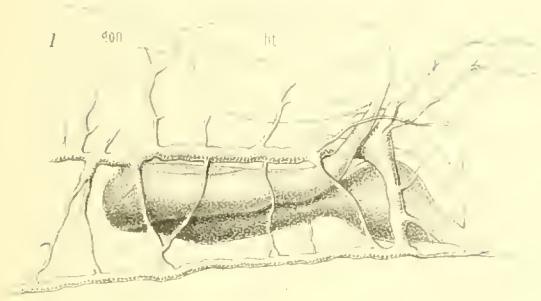
PLATE 11.

PLATE 11.

Fig. 1. Reconstruction of the posterior end of Drepanomenia vampyrella.
Fig. 2. Same of anterior end of Strophomenia spinosa, large specimen.
Fig. 3. Same of anterior end of Alexandromenia valida.
Fig. 4. Same of posterior end of Strophomenia farcimen.
Fig. 5. Same of posterior end of Pronomenia hawaiiensis.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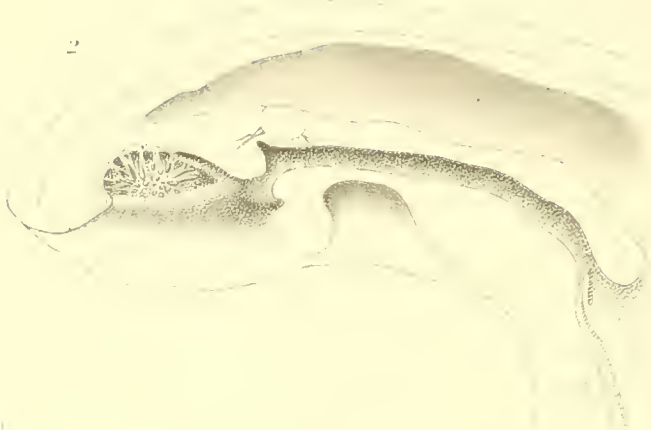
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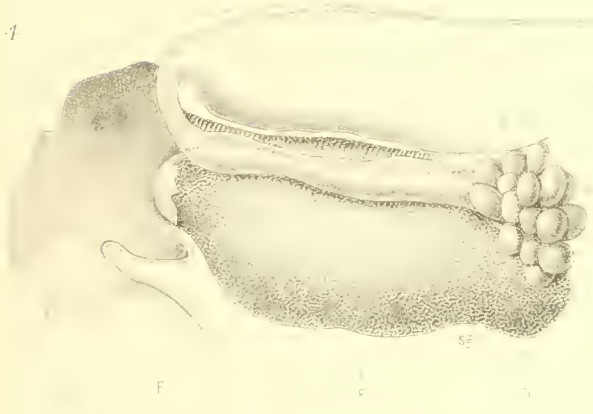
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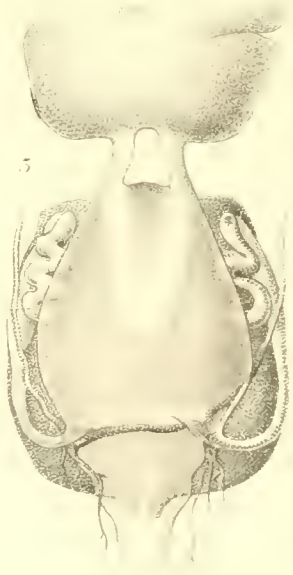
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PLATE 12.

Fig. 1. Reconstruction of anterior end of Strophomenia scandens.

Fig. 2. Section through dorso-terminal sense organ of Alexandromenia valida.

Fig. 3. Reconstruction of posterior end of Strophomenia spinosa, small specimen.

Fig. 4. Reconstruction of posterior end of Chaetoderma attenuata, showing principal nerves, two (brn) passing into the gill.

Fig. 5. Reconstruction of anterior part of nervous system of Alexandromenia agassizi.

Fig. 6. Same of posterior end.

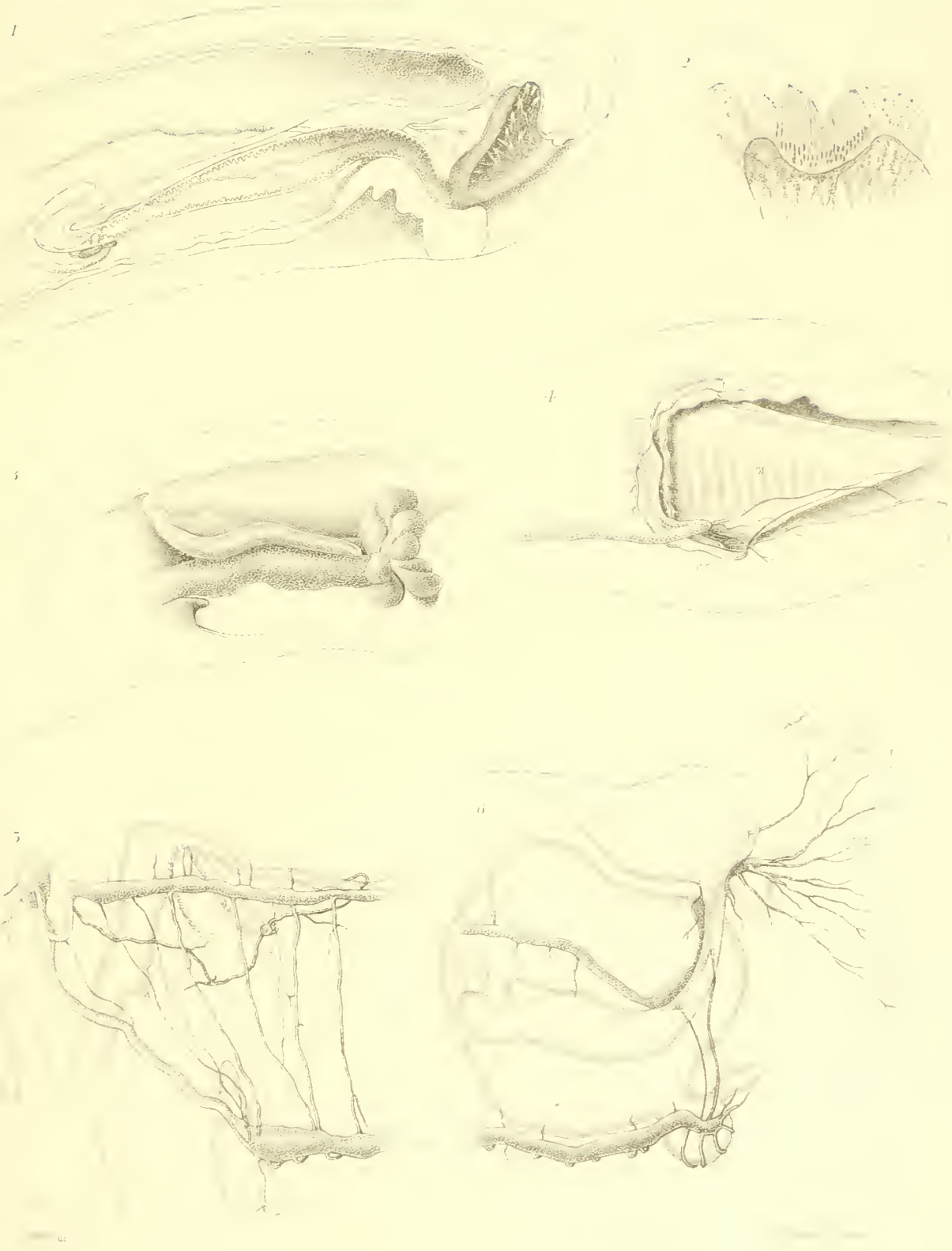

PLATE 13.

PLATE 13.

Fig. 1. Reconstruction of anterior end of Dorymenia acuta, showing nervous system. Labio-buccal system heavily shaded.

Fig. 2. Same of posterior end of Strophomenia scandens.

Fig. 3. Same of anterior end of Chaetoderma erudita.

Fig. 4. Same of posterior end of Proneomenia hawaiiensis.

PLATE 14.

PLATE 14.

Cross sections of Proneomenia hawaiiensis. × 33.

Figs. 1, 2, 7 correspond to lines A, B, C in fig. 2, pl. 5 (anterior end) and figs. 5, 6, 8 to D, E, F in fig. 4, pl. 13 (posterior end). In fig. 1, im, om represent inner and outer atrial ridge; os, external sensory ridge.

Fig. 3. Section through middle of body.

Fig. 4. Section through animal about one fifth body length from anterior end

Fig. 9. Section through body a short distance behind pharynx.

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PLATE 15.

Figs. 1–7, 9–12. Sections of Dorymenia acuta. × 50; Fig. 8. Halomenia gravida.

Figs. 1, 2 correspond to lines A, B indicated in fig. 7, pl. 15 (anterior end), and figs. 4, 6 to D, C, in fig. 4, pl. 6 (posterior end).

Fig. 3. Section through dorso-terminal sense organ.

Fig. 5. Cross section of penial spine. × 205.

Fig. 7. Longitudinal section of anterior end of body.

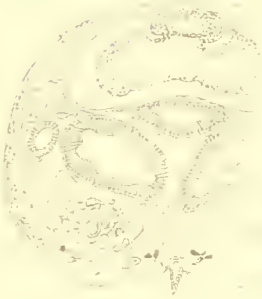
Fig. 8. Cross section corresponding to line D, fig. 5, pl. 3.

Fig. 9. Cross section of young animal, posterior end.

Fig. 10. Longitudinal section through base of penial spine. × 205.

Fig. 11. Section through dorso-terminal sense organ. × 205.

Fig. 12. Section through atrial cavity.



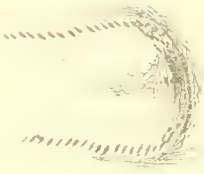


PLATE 16.

PLATE 16

Cross sections of Strophomenia scandens. × 33.

Fig. 1. In region of brain.
Fig. 2. Behind pharynx.
Fig. 3. In middle of body.
Fig. 4. Through pharynx opposite anterior pedal gland outlet.
Fig. 5. Through seminal receptacles.
Fig. 6 Through mid section of coelomoducts.
Fig. 7. Opposite junction of pharynx and mid gut.
Fig. 8. Through junction of coelomoducts.
Fig. 9 Through outlet of coelomoducts into cloaca.

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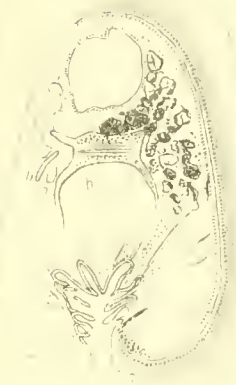

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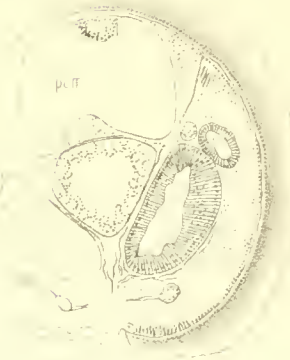

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PLATE 17.

PLATE 17.

Figs. 1–7. Strophomenia spinosa, × 33. Figs. 8, 9, 13. S. ophidiana, × 24 Figs. 10–12, 14–17, S. farcimen, × 33.

Figs. 1, 2, 3 cross sections of S. spinosa (large specimen) along lines A, B, C indicated in fig. 2, pl. 8 (the lines A, B should be perpendicular to the cuticle).

Fig. 4. Cross section through radula and salivary gland outlet, S. spinosa.

Figs. 5, 6, 7 are through fig. 4, pl. 9 (posterior end).

Figs. 8, 9, 13 are cross sections of S. ophidiana along lines A, B, C of fig. 5, pl. 8.

Figs. 10, 11, 16 are cross sections of S. farcimen along lines, A, B, C indicated in fig. 1, pl. 7 (anterior end).

Figs. 14, 15, 12, of same species, correspond to lines D, E, F, of fig. 4, pl. 11 (posterior end).

Fig. 17. Spines of Strophomenia farcimen. × 210.

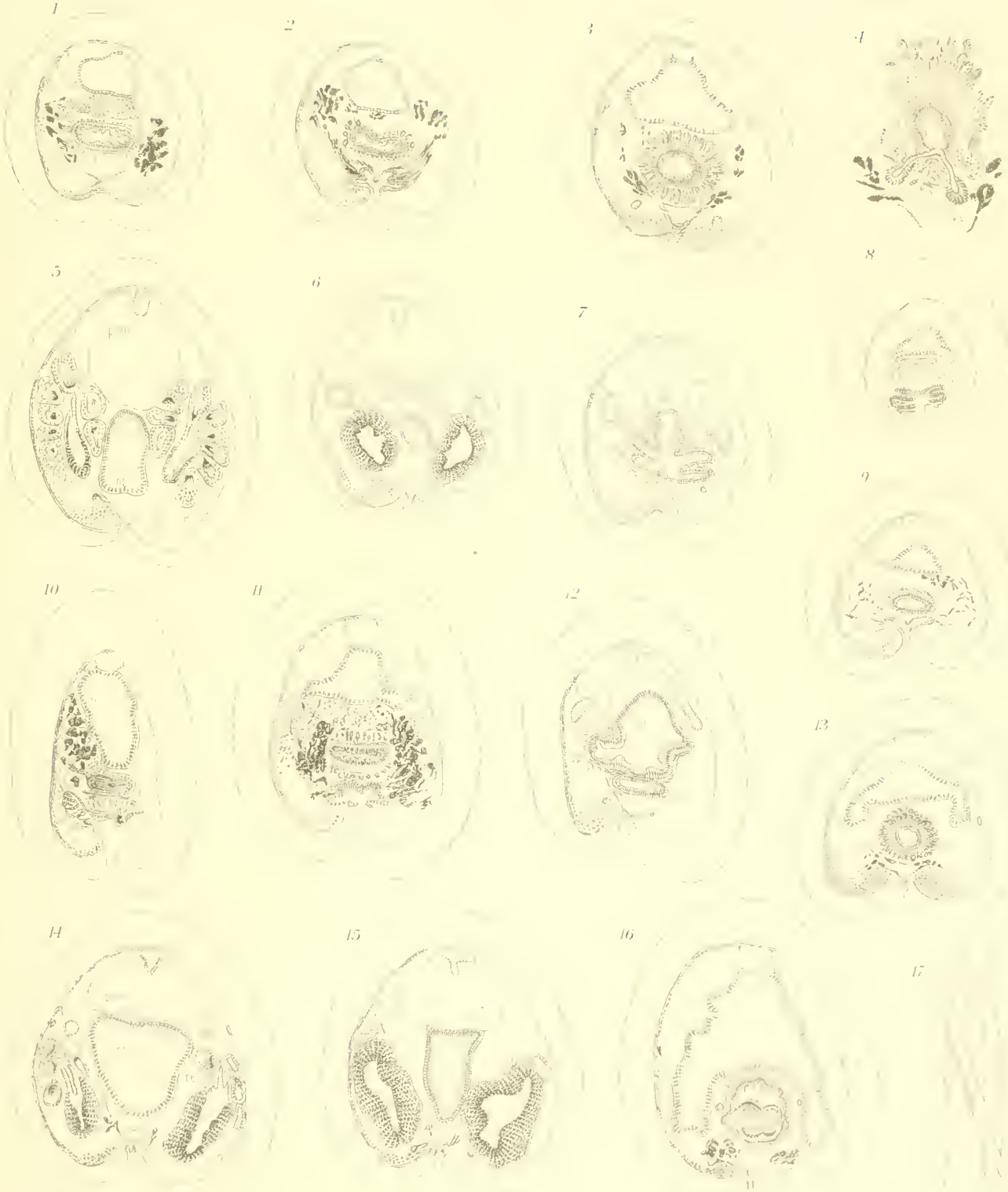

PLATE 13.

PLATE 18.

Figs. 1–4. Strophomena ophidiana × 24. Figs. 5–12. S. triangularis. × 55. Fig. 13. S. farcimen. × 60.

Fig. 1. Cross section of S. ophidiana along line D of fig. 5, pl. 8.

Figs. 2, 3, 4 of same species are along lines, E, F, G, fig. 1, pl. 9.

Figs. 8, 12, 10, 11 of S. triangularis correspond to lines D, E, F, G, fig. 3, pl. 9.

Figs. 5, 6, 9 correspond to lines A, B, C, fig. 6, pl. 36.

Fig. 7. Section through mid gut behind pharynx.

Fig. 13. Section through mid gut of S. farcimen in region of salivary glands.

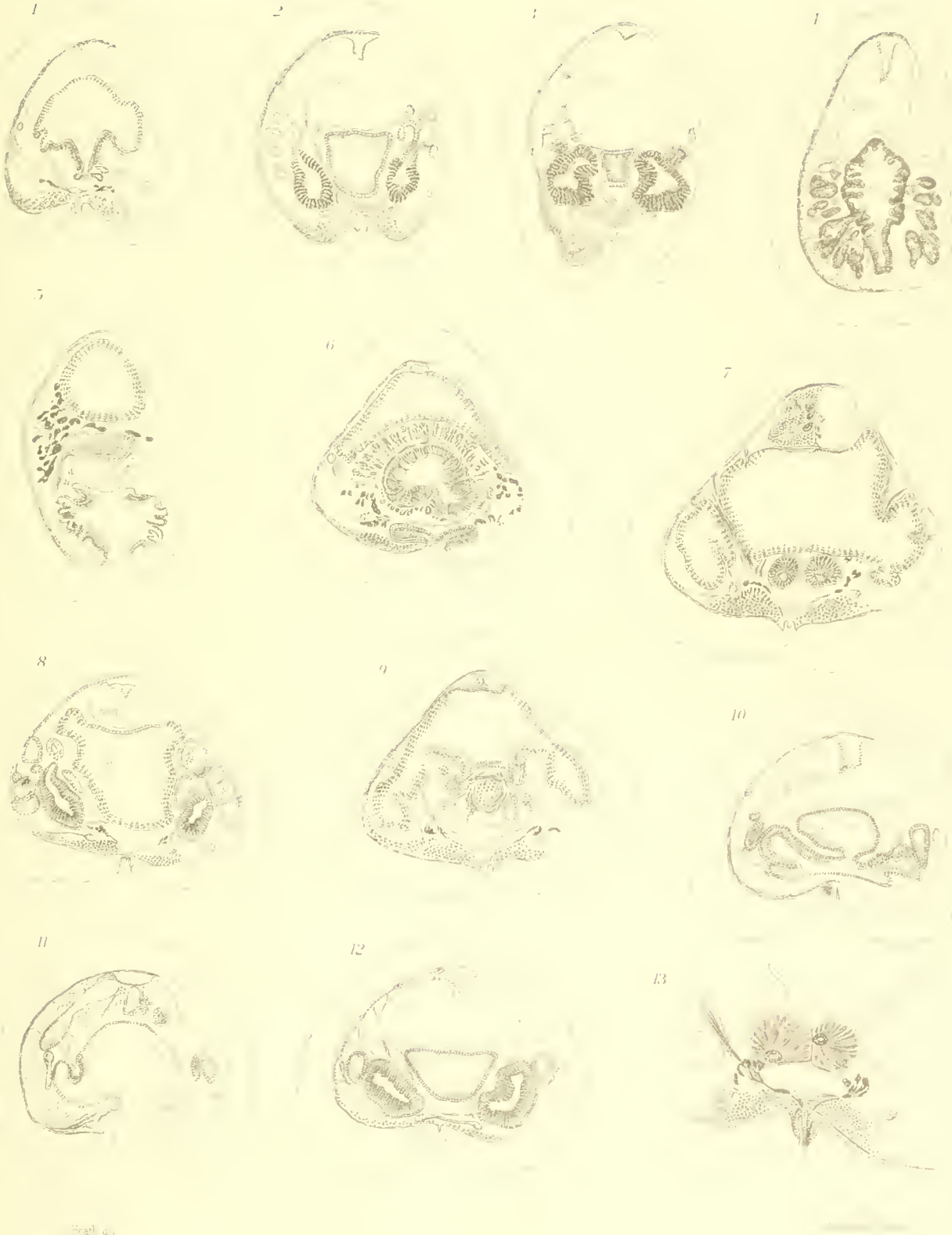
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PLATE 19.

PLATE 19.

Figs. 1–3, 5, 6, 9. Lophomenia spiralis. × 35; Figs. 1, 7, 8, 10–15. Herpomenina platypoda. × 60.

Figs. 1, 2, cross sections of much curved specimen of Lophomenia spiralis. × 45.

Fig. 3. Section behind pharynx.

Figs. 5, 6, 9 (same species) correspond to lines B, C, A, fig. 6, pl. 8.

Figs. 1, 7, 8, cross sections of Herpomenia platypoda along lines A, C, B in fig. 1, pl. 8. × 60.

Figs. 10, 11. Sections through posterior end of H. platypoda along lines D, E, (which should incline to left) fig. 3, pl. 8.

Fig. 12. Section through dorso-terminal sense organ. × 205.

Fig. 13. Section through salivary ducts, showing entrance of ductules from gland cells.

Figs. 11, 15. Longitudinal sections through posterior end of H. platypoda.

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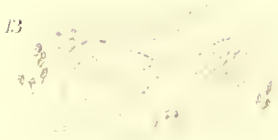
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PLATE 20.

Alexandromenia agassizi. × 25.

Figs. 1, 2, 4, 9 correspond to lines A, D, B, C of fig. 3, pl. 7 (anterior end).
Fig. 3, 5, 7, 8, are along lines F, G, H, E, of fig. 5, pl. 7 (posterior end). Fig. 7. × 20.
Fig. 6. Cross section of heart at junction of its two divisions.

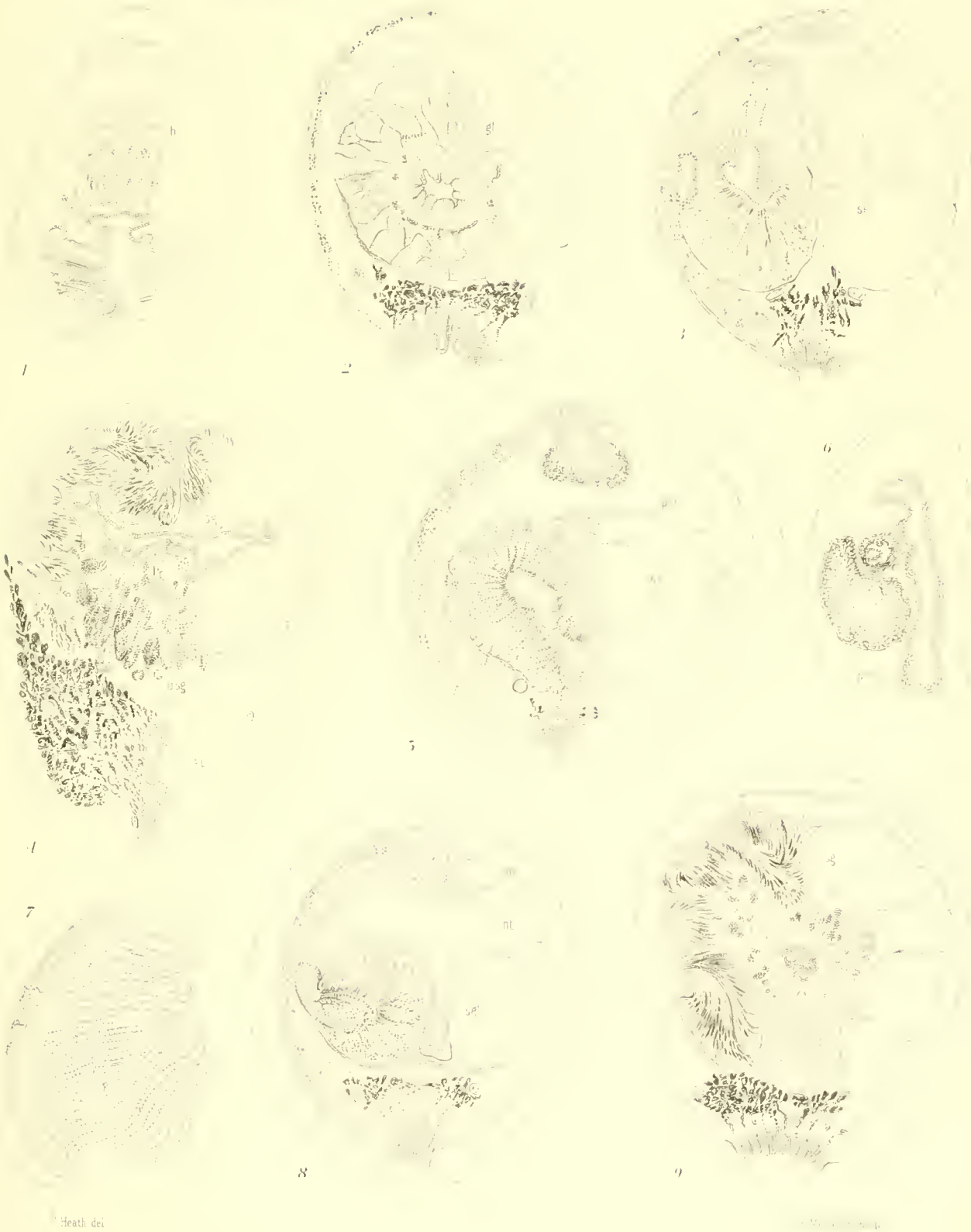
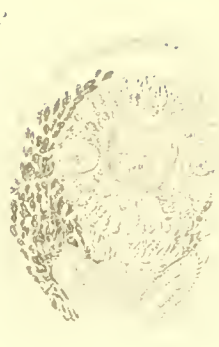


PLATE 21.

PLATE 21.

Figs. 1–6. Alexandromena valida. × 28. Figs. 7–13. Limifossor talpoideus. × 33.

Figs. 1, 2, 4. Cross sections along lines A, B, C in fig. 3, pl. 11 (anterior end).
Figs. 3, 5, 6. Through posterior end of body.
Figs. 7, 8, 9 correspond to lines A, B, C in fig. 4, pl. 10 (anterior end).
Fig. 10. Chlorogogue or concrement bearing cells of L. talpoideus, from sides of ventral sinus. × 555.
Fig. 11. Section through brain.
Fig. 12. Hypodermis of L. talpoideus. × 255.
Fig. 13. Section through heart and pericardium. × 50.



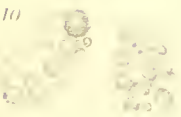


PLATE 22.

PLATE 22.

Cross sections of Halomenia gravida. × 55.

Figs. 1, 2, 3 correspond to lines A, B, C in fig. 3, pl. 5 (anterior end).

Fig. 4. Section through body behind pharynx.

Fig. 5. Salivary gland lobules opening into main duct.

Figs. 6, 8, 11 (see fig. 8, pl. 15) correspond to lines E, F, G in fig. 5, pl. 3 (posterior end).

Fig. 7. Longitudinal section through advanced larva, showing cerebral ganglion chain of nuclei, stomodaeum, st, and early stage in the development of the anterior pedal gland and outlet, f.

Fig. 9. Section through anterior division of heart.

Fig. 10. Section through junction of two divisions of heart.

Fig. 12. Section through dorso-terminal sense organ.

Fig. 13. Spines from middle of body. × 300.

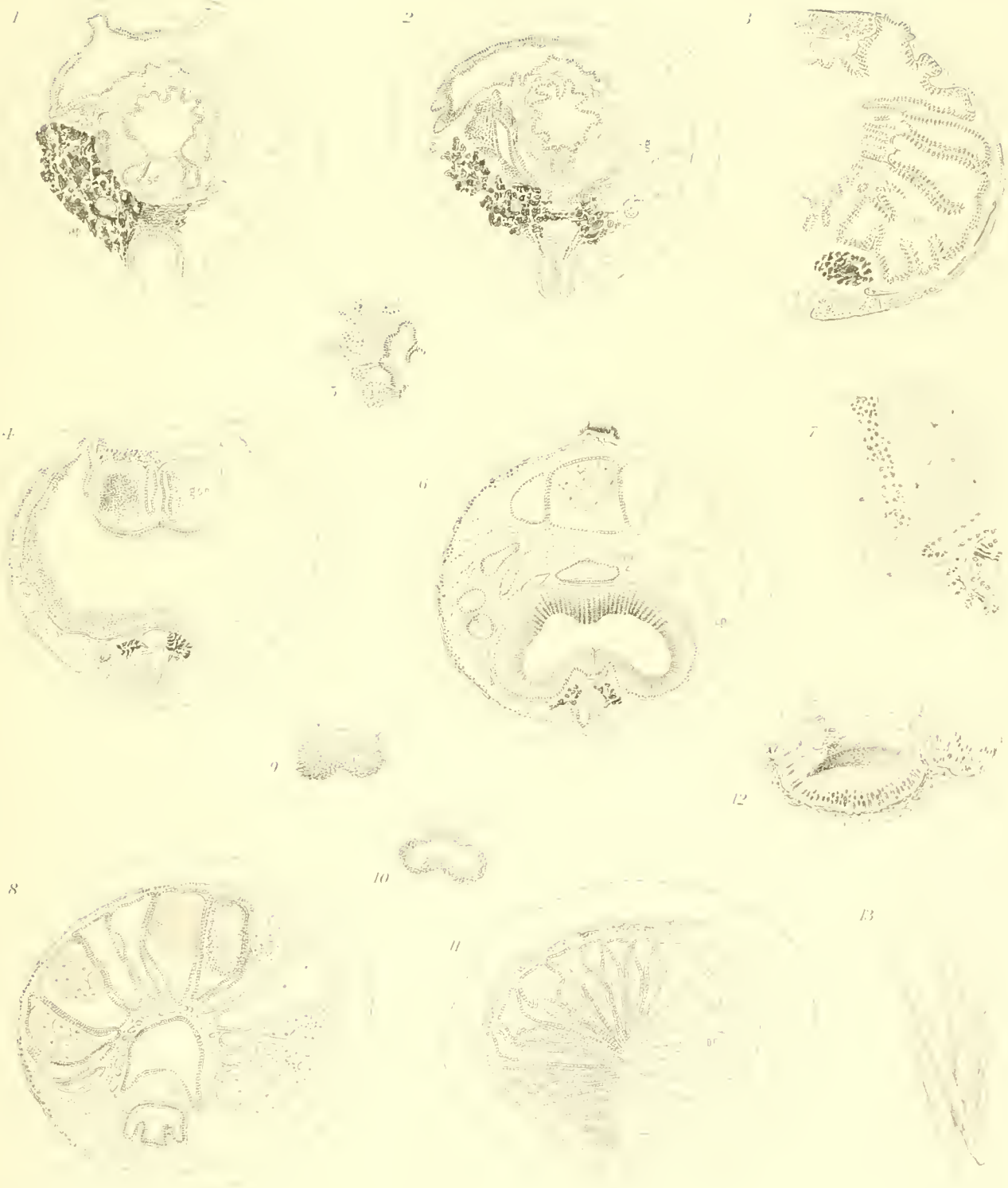


PLATE 23.

PLATE 23.

Cross sections of Dondersia californica. × 60

Figs. 1, 2, 3, 5 correspond to lines A, B, C, D, fig. 4, pl. 5 (anterior end).
Fig. 4. Through anterior end of mid gut.
Figs. 6, 9 are along lines G, F of fig. 2, pl. 6 (posterior end).
Fig. 7. Though middle of body.
Fig. 8. Section through radula. × 555.

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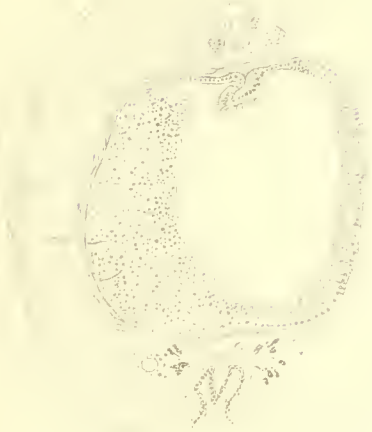

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PLATE 24.

PLATE 24.

Figs. 1–5, 11. Sections of Ichthyomenia porosa. × 55. Fig. 6–10, 12–14. Strophomenia regularis. × 55.

Figs. 1, 4, 11 of I. porosa, correspond to lines B, C, A, fig. 6, pl. 5.

Figs. 2, 5 are along the lines E, D, fig. 1, pl. 6 (posterior end).

Fig. 3. Section through middle of body.

Figs. 6, 8, 9, 10, of S. regularis, are along the lines, C, D, B, A in fig. 8, pl. 26 (in fig. B read el in place of et).

Fig. 7. Section of cuticle and hypodermis of S. regularis. × 205.

Fig. 12. Section through one sense organ of anterior end of I. porosa. × 555.

Fig. 13. Section through one seminal receptacle and several stalks of S. regularis. × 255.

Fig. 14. Blood corpuscles of S. regularis. × 555.

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PLATE 25.

PLATE 25.

Sections of Chaetoderma attenuata. × 33.

Fig. 1. Section through brain.
Fig. 2. Section through radula.
Fig. 3. Section through junction of stomach and intestine.
Fig. 4. Section through suprarectal commissure.
Fig. 5. Section through outlet of coelomoduct (pores omitted in figure).
Fig. 6. Section through posterior end of prothorax. × 60.
Fig. 7. Hypodermis, showing gland cells and attached fibres. × 555.
Fig. 8. Section through heart.
Figs. 9, 10. Two successive sections through the subradular ganglion and connectives. × 135.

PLATE 26.

PLATE 26.

Figs. 1–7. Chaetoderma argentea. × 33; Fig. 8. Strophomenia regularis. Fig. 9. Alexandromenia agassizi.

Fig. 1. Through brain region.
Fig. 2. Through radula.
Fig. 3. Through heart and coelomoducts.
Fig. 4. Through suprarectal commissure.
Fig. 5. Through region of outlet of coelomoducts.
Fig. 6. Through posterior end of prothorax.
Fig. 7. Through junction of pharynx and stomach.
Fig. 8. Reconstruction of posterior end of Strophomenia regularis.
Fig. 9. A portion of the ventral salivary glands and duct in Alexandromenia agassizi.

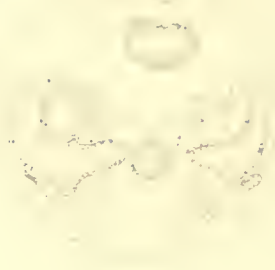
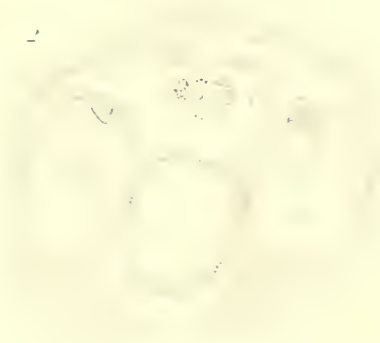


PLATE 27.

PLATE 27.

Figs. 1, 2, 4–11. Cross sections of Chaetoderma montereyensis. (× 40.) Fig. 3. C. nanula.

Fig. 1. Through brain region.
Fig. 2. Through heart and coelomoducts.
Fig. 3. Through junction of pharynx and stomach.
Fig. 4. Through radula.
Fig. 5. Through labio-buccal ganglia and glands entering pharynx.
Fig. 6. Through heart and coelomoducts.
Fig. 7. Dorso-terminal sense organ.
Fig. 8. Through suprarectal commissure.
Fig. 9. Through outlet, on left, of coelomoduct.
Fig. 10. Through junction of pharynx and stomach.
Fig. 11. Through brain and anterior buccal plate of small specimen.



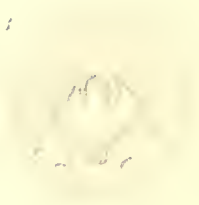
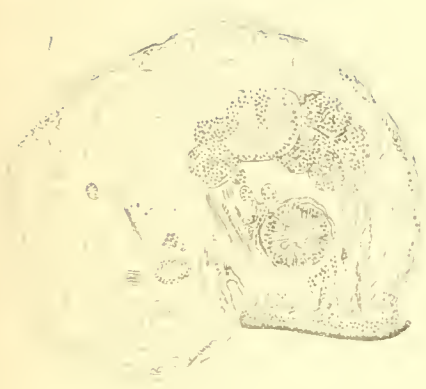


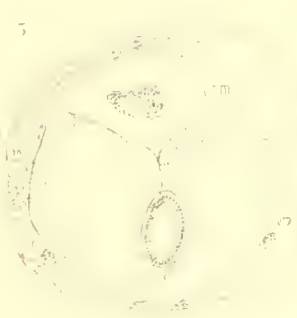
PLATE 28.

PLATE 28.

Figs. 1–6, 8, 9. Cross sections of Chaetoderma hawaiiensis. × 55; Figs. 7, 10–12. Chaetoderma nanula. × 33.

Fig. 1. Through brain and buccal plate.
Fig. 2. Through radula.
Fig. 3. Through junction of pharynx and stomach.
Fig. 4. Through suprarectal commissure.
Fig. 5. Through heart and coelomoducts.
Fig. 6. Through outlet of coelomoduct, on left, and origin of pericardial opening.
Fig. 7. Through brain region.
Fig. 8. Through posterior end of prothorax.
Fig. 9. Longitudinal section of posterior end.
Fig. 10. Section through outlet of coelomoduct, on left.
Fig. 11. Through radula.
Fig. 12. Through suprarectal commissure.





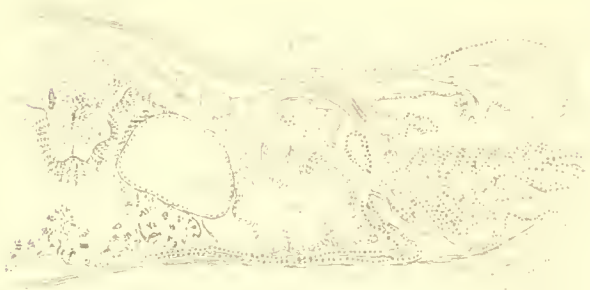


PLATE 29.

PLATE 29.

Figs. 1–5, 8, 12. Cross sections of Chaetoderma erudita. × 33. Figs. 6, 7, 9–11. Chaetoderma scabra. × 20.

Fig. 1. Through heart and coelomoducts.
Fig. 2. Close to junction of pharynx and stomach.
Fig. 3. Posterior end of prothorax.
Fig. 4. Through brain.
Fig. 5. Through outlet, on right, of coelomoduct.
Fig. 6. Suprarectal commissure.
Fig. 7. Through gills and cloacal chamber.
Fig. 8. Through radula.
Fig. 9. Through junction of pharynx and stomach.
Fig. 10. Through heart and coelomoducts.
Fig. 11. Through posterior end of prothorax.
Fig. 12. Through suprarectal commissure.

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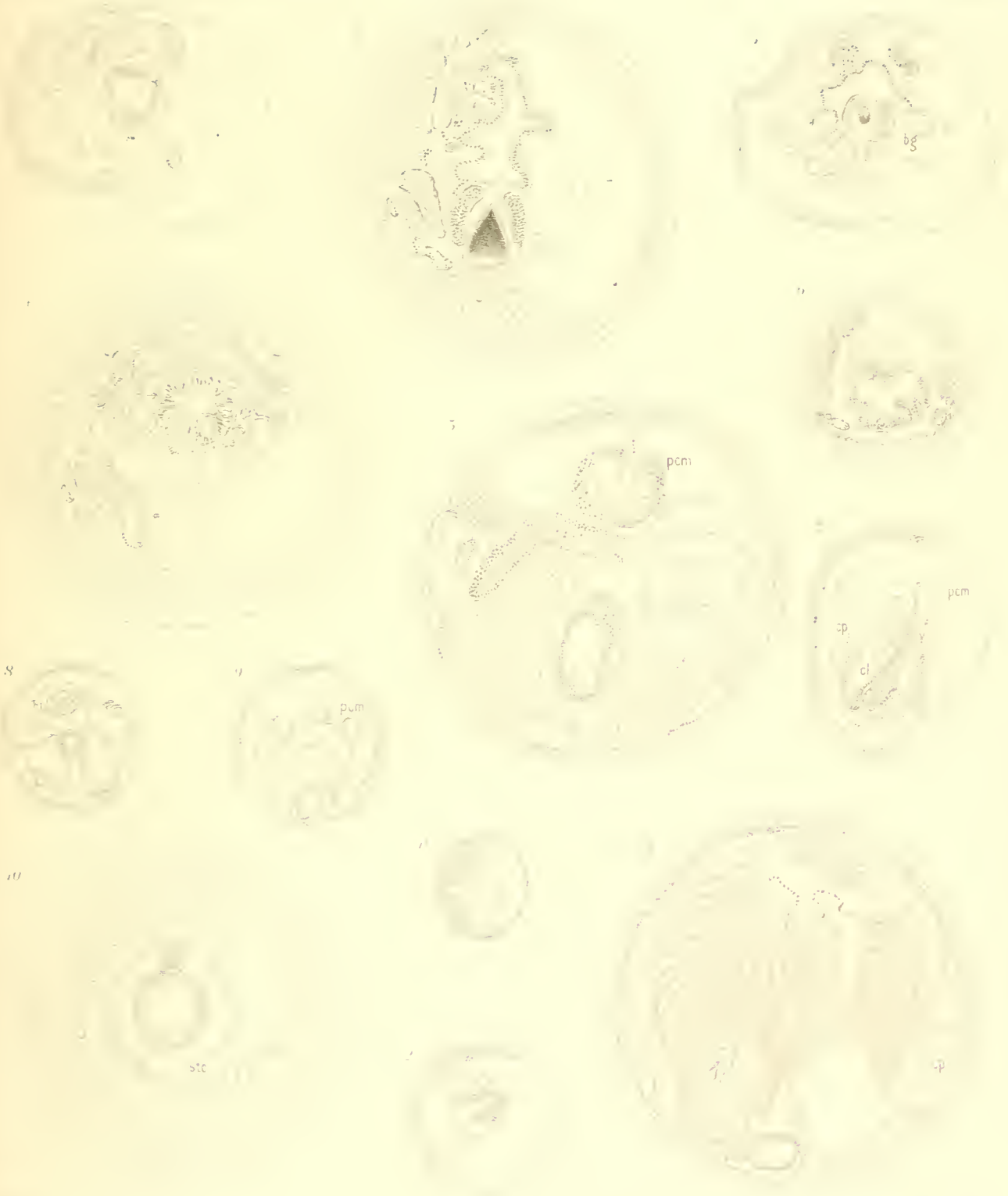
PLATE 30.

PLATE 30.

Figs. 1, 3. Chaetoderma scabra. × 33. Figs. 2, 4–6, 10, 13. Cross sections of Chaetoder
robusta. × 33. Figs. 7–9, 11, 12. Chaetoderma japonica. × 33.

Fig. 1. Through brain region.
Fig. 2. Through radula.
Fig. 3. Same. Through radula.
Fig. 4. Through brain region.
Fig. 5. Through suprarectal commissure.
Fig. 6. Through posterior end of prothorax.
Fig. 7. Though outlet, on left, of coelomoduct.
Fig. 8. Through heart and coelomoducts.
Fig. 9. Through suprarectal commissure.
Fig. 10. Through junction of pharynx and stomach.
Fig. 11. Through posterior end of prothorax.
Fig. 12. Through junction of pharynx and stomach.
Fig. 13. Through outlet, on left, of coelomoduct.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it demands no description. Posteriorly the gut narrows rapidly, becomes somewhat rectangular in cross section as it passes between the limbs of the shell gland, and shortly before its outlet in the cloaca develops moderately high folds.

The pericardial cavity is of very large size (Plate 18, figs. 2, 3), and the contained heart is of the usual greatly elongated type. There are no distinct signs of a division into auricle and ventricle though a valve-like flap near its anterior end may indicate such or possibly the commencement of the aorta, which for a considerable distance is of as great diameter as the heart itself and even in the head region continues of large calibre (Plate 18, fig. 1). Its relations to the gonad and visceral cavity are similar to what occurs in *S. triangularis*. In the posterior part of the body the channels are more than usually ill defined, but the course of the blood is essentially the same as in the other species of the genus. The corpuscles possess the characteristic elliptical or pointed ovate form, and are accompanied by a relatively large number of leucocytes.

The gonad is fully developed, of relatively large size and the sex products are arranged in the customary fashion. Throughout its entire extent, but especially in the posterior half of the animal, the normal reproductive elements are associated with large masses of eggs in all stages of degeneration. This may be due to *post mortem* changes, but the sharply defined character of the various stages of the spermatozoa, ova, blood corpuscles, and other cellular elements in various parts of the body argues against such a view. In some species of Chitons (*e. g. Ischnochiton magdalenensis*) a considerable number of ova do not pass to the exterior during the egg-laying process, but undergo disintegration and are absorbed. Appearances indicate that this is the state of affairs in the present species, and the almost empty condition of the seminal receptacles further indicates that the breeding season has passed.

The ducts leading from the pericardial cavity are relatively slender though they enlarge somewhat before entering the shell gland, and as the cells change from a cubical to a columnar form they become increasingly glandular. An unusually large number of seminal vesicles are present, twenty-three occurring on the side of the body represented (Plate 9, fig. 1). In these the distal, usually vesicular portion is exceptionally small (Plate 18, fig. 4) but the diameter may be somewhat increased when the organs are filled with sperms. These bodies are attached not only to the forward end of the shell gland but several of them open into the dorsal section of the gonoduct. The component cells are columnar and show at various points faint signs of glandular activity. The shell gland on the other hand is highly glandular, more than usually irregular in outline and as

usual in the genus unites with its fellow of the opposite side so close to the cloaca that two openings appear to be present. The cells are all of columnar form and are of one type judging from the darkly staining granular secretion. As in other species of the genus a diverticulum of the cloacal wall is present ventral to the outlet of the shell gland, but there are no indications that it is of any especial significance.

In the other species of the genus Strophomenia described in the present paper there are from few to many diverticula extending outwardly from the cloacal wall, but they never reach the excessive development existing in this species. These are shown, somewhat diagrammatically (Plate 9, fig. 1). The cells are usually columnar and are filled with a finely granular substance which in various places is in the act of escaping into the cloacal cavity.

The brain, clearly bilobed, is located against the under side of the intestinal coecum at the level of the posterior border of the atrium (Plate 8, fig. 5). From it the usual three pairs of nerves originate, that after branching unite with ganglionic masses attached to the bases of the cirri or without such union pass to the body wall. The connectives to the lateral, pedal, and labio-buccal systems arise in the customary situations and the relations of the ganglia themselves, so far as they have been determined, are typical. Pedal commissures and latero-pedal connectives occur at frequent, though not perfectly regular, intervals and a corresponding number of unusually heavy nerves arise from the dorsal surface of the lateral ganglia. These have in several cases been followed close to the mid dorsal line but that they form commissures is not assured. They probably innervate the neighboring somatic musculature and hypodermis.

Posteriorly the pedal cords, united by commissures to the anterior cloacal wall, branch repeatedly in this last named locality and innervate the body and cloacal walls and some of the fibres become imbedded in the shell gland. The lateral cords at this same level likewise branch repeatedly and supply the same structures as the pedal, though more dorsally, and in addition give off a few small nerves that attach themselves to the pericardial wall. A very few branches from these last named nerves have been traced a short distance into the heart. The pedal and lateral cords are posteriorly united by one delicate branch; others may exist, but the nerves are not sufficiently differentiated from the surrounding tissue to permit of their being followed for any considerable distance. It is a peculiar fact that no trace of a dorsal posterior commissure uniting the lateral cords has been found to exist.

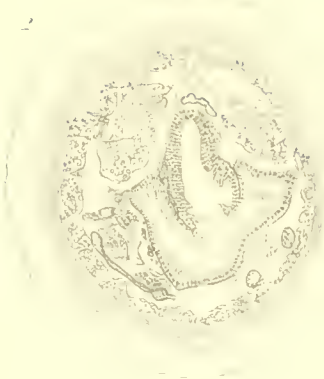
The labio-buccal connectives arise to the inside of the connectives leading

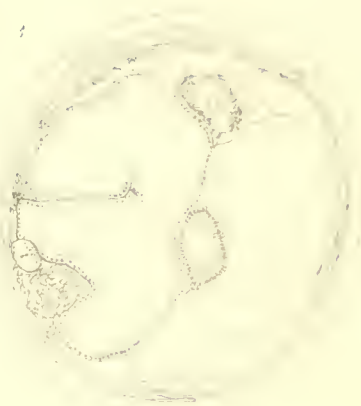
PLATE 31.

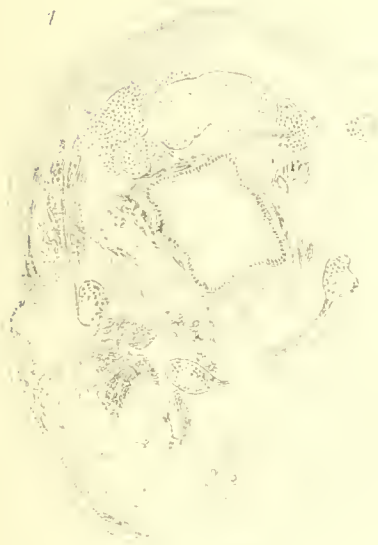
PLATE 31.

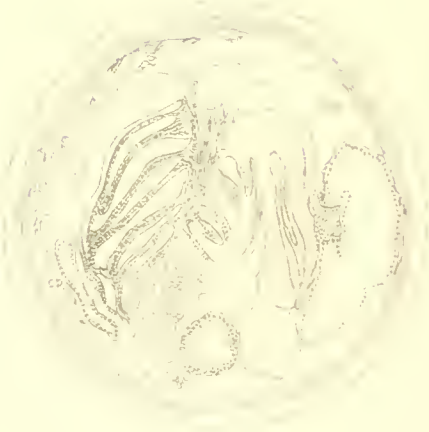
Figs. 1–4, 7, 8, 10. Cross sections of Chaetoderma californica. (× 33.) Figs. 5, 6. Chaetoderma japonica. × 33. Fig. 9. Proneomenia hawaiiensis.

Fig. 1. Through radula.
Fig. 2. Through junction of pharynx and stomach.
Fig. 3. Through heart and coelomoducts.
Fig. 4. Through brain region.
Fig. 5. Through brain of Chaetoderma japonica.
Fig. 6. Through radula, same species.
Fig. 7. Through outlet of coelomoduct, on left.
Fig. 8. Pharynx and glands in front of radula.
Fig. 9. External sensory atrial ridge of Proneomenia hawaiiensis; os, ridge resting upon ganglion cells; om, outer atrial ridge; c, cirrus.
Fig. 10. Through suprarectal commissure.









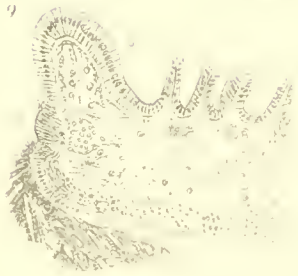
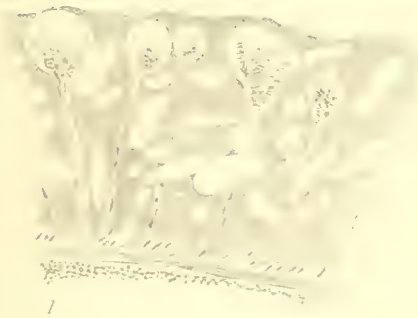


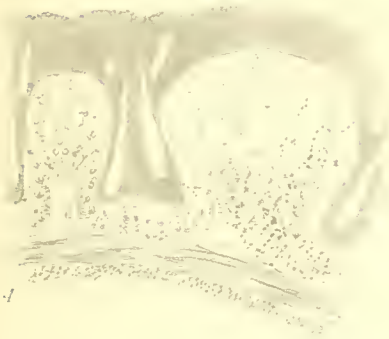
PLATE 32.

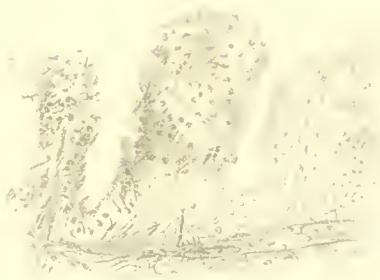
PLATE 32.

Cuticle and hypodermis from side of head unless otherwise stated.

Fig. 1. Hypodermis and its products in Strophomenia spinosa, large specimen. × 205.
Fig. 2. Same in Lophomenia spiralis. × 255.
Fig. 3. Same in Strophomenia scandens. × 155.
Fig. 4. Same in Halomenia gravida. × 225.
Fig. 5. Perforation of the somatic musculature in H. gravida by a diverticulum of the mid gut which comes in contact with a modified hypodermal papilla; s, blood sinus. × 255.
Fig. 6. Hypodermis of Drepanomenia vampyrella. × 255.
Fig. 7. Same of Ichthyomenia porosa. × 330.
Fig. 8. Same of Dondersia californica. × 555.
Fig. 9. Section through the dorsal sense organ of Strophomenia scandens. × 300.
Fig. 10 Same of Proneomenia hawaiiensis; ne, nerve. × 180.
Fig. 11. Same of Lophomenia spiralis; ne, nerve. × 150.







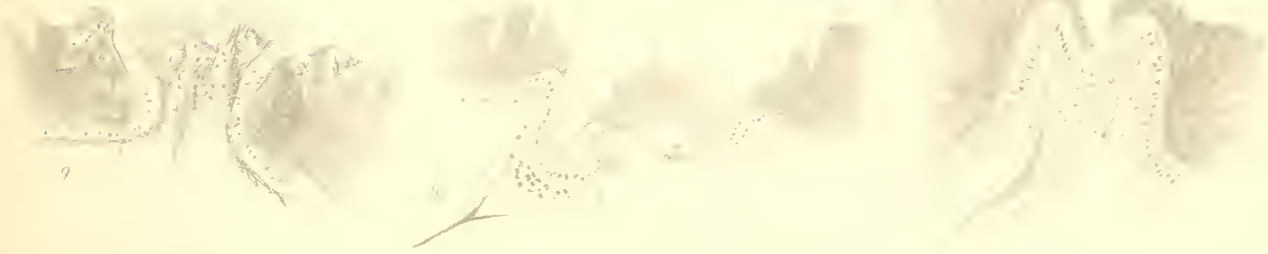


PLATE 33.

PLATE 33.

Cuticle and hypodermis from side of head unless otherwise stated.

Fig. 1. Strophomenia triangularis. × 200.
Fig. 2. Strophomenia farcimen. × 300.
Fig. 3. Proneomenia hawaiiensis. × 300.
Fig. 4. Dorymenia acuta. × 330.
Fig. 5. Alexandromenia agassizi. × 200.
Fig. 6. Proneomenia insularis. × 400.
Fig. 7. Strophomenia spinosa, dorsal side. × 200.
Fig. 8. Alexandromenia valida. × 260.
Fig. 9. Strophomenia ophidiana. × 200.

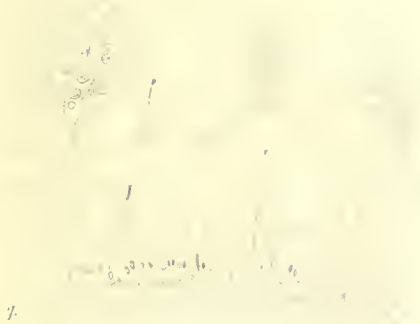


PLATE 34.

PLATE 34

Fig. 1. Cross section through radula sac of Lophomenia spiralis. × 57.

Fig. 2. Longitudinal section through radula and subradular organ of Proneomenia hawaiiensis. × 80.

Fig. 3. Dorsal view of radula of Limifossor talpoideus. × 135.

Fig. 4. Two rows of teeth of Strophomenia triangularis. × 330.

Fig. 5. Portion of radula of Alexandromenia agassizi. × 255.

Fig. 6. Side view of radula of Limifossor talpoideus. × 135.

Fig. 7. Teeth of Dorymenia acuta (mid line to left). × 330.

Fig. 8. Teeth of Strophomenia spinosa, large individual. × 555.

Fig. 9. Same species, small individual. × 330.

Fig. 10. Same species, small individual. × 330.

Fig. 11. Side view of teeth of Dorymenia acuta. × 330.

Fig. 12. Cross section of radula of Halomenia gravida. × 330.

Fig. 13. Proneomenia hawaiiensis, showing 7 of the 40 teeth of each transverse row; m, mid line. × 255.

Fig. 14. Tooth of Alexandromenia valida. × 200.

Fig. 15. Portion of radula of Strophomenia farcimen. × 255.

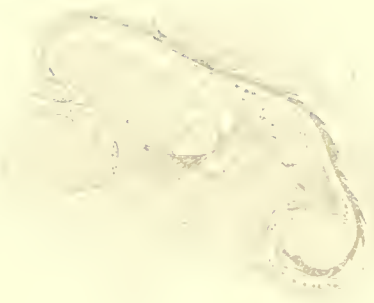


PLATE 35.

PLATE 35.

Fig. 1. Limifossor fratula. Section through region of salivary glands. × 28.

Fig. 2. Same through muscle 17 (fig. 4, pl. 10).

Fig. 3. Same through posterior end of radula support. × 28.

Fig. 4. Same in region of heart.

Fig. 5. Same through opening of digestive gland.

Figs. 6, 7, 9. Development of ova in Herpomenia platypoda. In fig. 6 the nuclei of probable follicle cells (fc) are intact; in fig. 7 the membrane has dissolved and the scattered chromosomes are becoming vesicular; in fig. 9 the ovum is almost mature and the vesicles (cr) of relatively large size. × 555.

Fig. 8. Longitudinal section through region of radula of Chaetoderma erudita, showing subradular ganglion, sn. × 135.

Fig. 10. Section through brain of Limifossor fratula. × 28.

Fig. 11. Protozoa encysted in wall of digestive tract of Chaetoderma californica.

Fig. 12. Section through dorso-terminal sense organ of Dondersia californica. × 333.

Fig. 13. Blood corpuscles of Proneomenia hawaiiensis. × 450.

Fig. 14. Section through Proneomenia insularis.

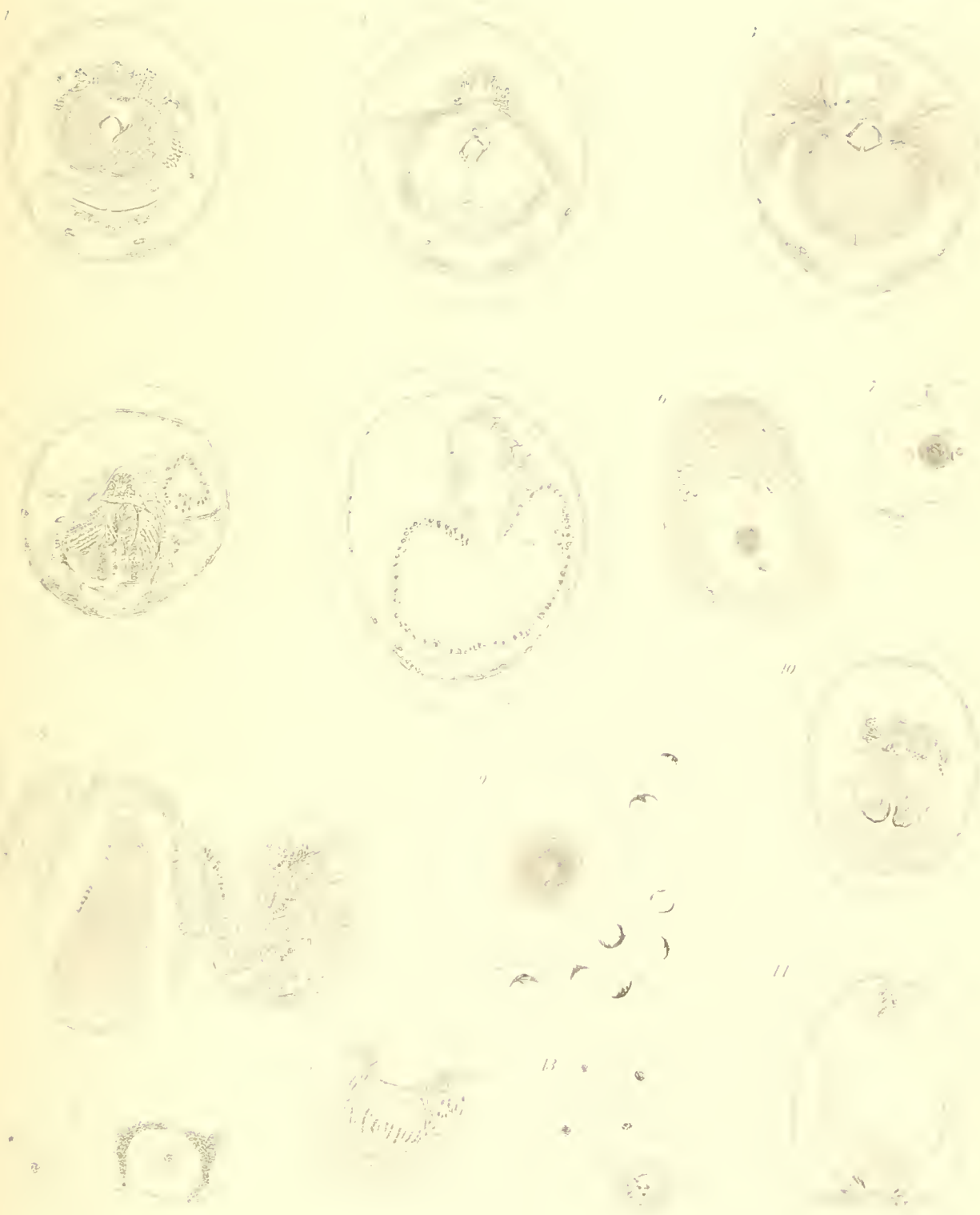


PLATE 36.

PLATE 36.

Fig. 1. Reconstruction of posterior end of Chaetoderma argentea.

Fig. 2. Same of Chaetoderma attenuata.

Fig. 3. Advanced stage in spicule development, the matrix cells retaining their attachment to the spine. Proneomenia hawaiiensis. × 555.

Fig. 4. Somewhat earlier stage than fig. 3. × 555.

Fig. 5. Completion of spicule development and commencement of shifting of matrix cells. × 555.

Fig 6. Reconstruction of anterior end of Strophomenia triangularis.

Fig. 7. Early stage in development of spine in Proneomenia hawaiiensis. × 555.

Fig. 8. Hypodermis in Limifossor fratula. × 255.

Fig. 9. Posterior end of Alexandromenia agassizi. × 3.

Fig. 10. Papilla and outlet of salivary gland in A. agassizi.

Fig. 11. Very early stage in development of spine in Proneomenia hawaiiensis. × 555.

Fig. 12. Blood corpuscles of Strophomenia scandens. × 450.

Fig. 13. Same of Chaetoderma hawaiiensis. × 450.

Fig. 14. Same of Lophomenia spiralis. × 450.

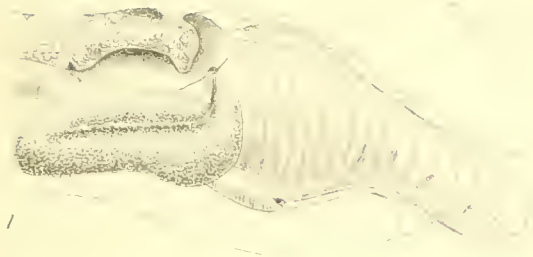
Fig. 15. Spines of Strophomenia triangularis. × 150.

Fig. 16. Same of Strophomenia spinosa. × 205.

Fig. 17. Same of Strophomenia ophidiana. × 205.

Fig. 18. Completed development of radially directed spine of Proneomenia hawaiiensis; and developing papilla. × 555.

Fig. 19. Base of gill plates and attached gland cells (gc), Alexandromenia agassizi; ne, nerve.



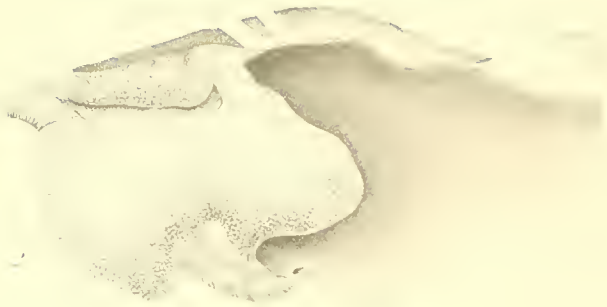


PLATE 37.

PLATE 37.

Fig. 1. Spicules of Ichthyomenia porosa. × 480.
Fig. 2. Of Chaetoderma montereyensis, small specimen. × 80.
Fig. 3. Of Chaetoderma montereyensis, large specimen. × 80.
Fig. 4. Of Chaetoderma robusta. × 80.
Fig. 5. Of Proneomenia hawaiiensis. a × 330; b × 130.
Fig. 6. Of Chaetoderma argentea. × 135.
Fig. 7. Of Drepanomenia vampyrella. × 135.
Fig. 8. Of Chaetoderma attenuata. × 135.
Fig. 9. Of Alexandromenia agassizi. × 335.
Fig. 10. Of Dorymenia acuta. × 135.
Fig. 11. Alexandromenia valida. × 180.
Fig. 12. Of Chaetoderma hawaiiensis. × 255.
Fig. 13. Of Lophomenia spiralis. × 335.
Fig. 14. Of Chaetoderma californica. × 135.
Fig. 15. Of Chaetoderma erudita. × 135.
Fig. 16. Of Proneomenia insularis. × 135.
Fig. 17. Strophomenia scandens. × 300.
Fig. 18. Of Chaetoderma nanula. × 135.
Fig. 19. Of Chaetoderma scabra. × 100.
Fig. 20. Of Chaetoderma sp.? Unidentified fragment, Alaska. × 135.

PLATE 38.

PLATE 38.

Fig. 1. Reconstruction of anterior end of Driomenia pacifica.
Fig. 2. Same, posterior end.
Fig. 3. Entire animal enveloped in small portion of hydroid colony, Sertularella sp. × 5.
Figs. 4, 5, 6, 8. Sections along lines A, C, B, D, in fig. 1. × 50.
Figs. 7, 9. Along lines E, F, of fig. 2. × 50.
Fig. 10. Section of hypodermis and cuticle. × 260.
Fig. 11. Same of Pachymenia abyssorum. × 60.

PLATE 39.

PLATE 39.

Fig. 1. Reconstruction of anterior end of Pachymenia abyssorum.
Fig. 2. Same, posterior end.
Fig. 3. Foot, same species, in middle of body.
Fig. 4. Pachymenia abyssorum. × 3.
Fig. 5. Spines of Driomenia pacifica.
Fig. 6, 8. Sections of Pachymenia abyssorum along lines B, D, fig. 1. × 25.
Fig. 7. Section of Driomenia pacifica along line G, fig. 2, pl. 38. × 50.

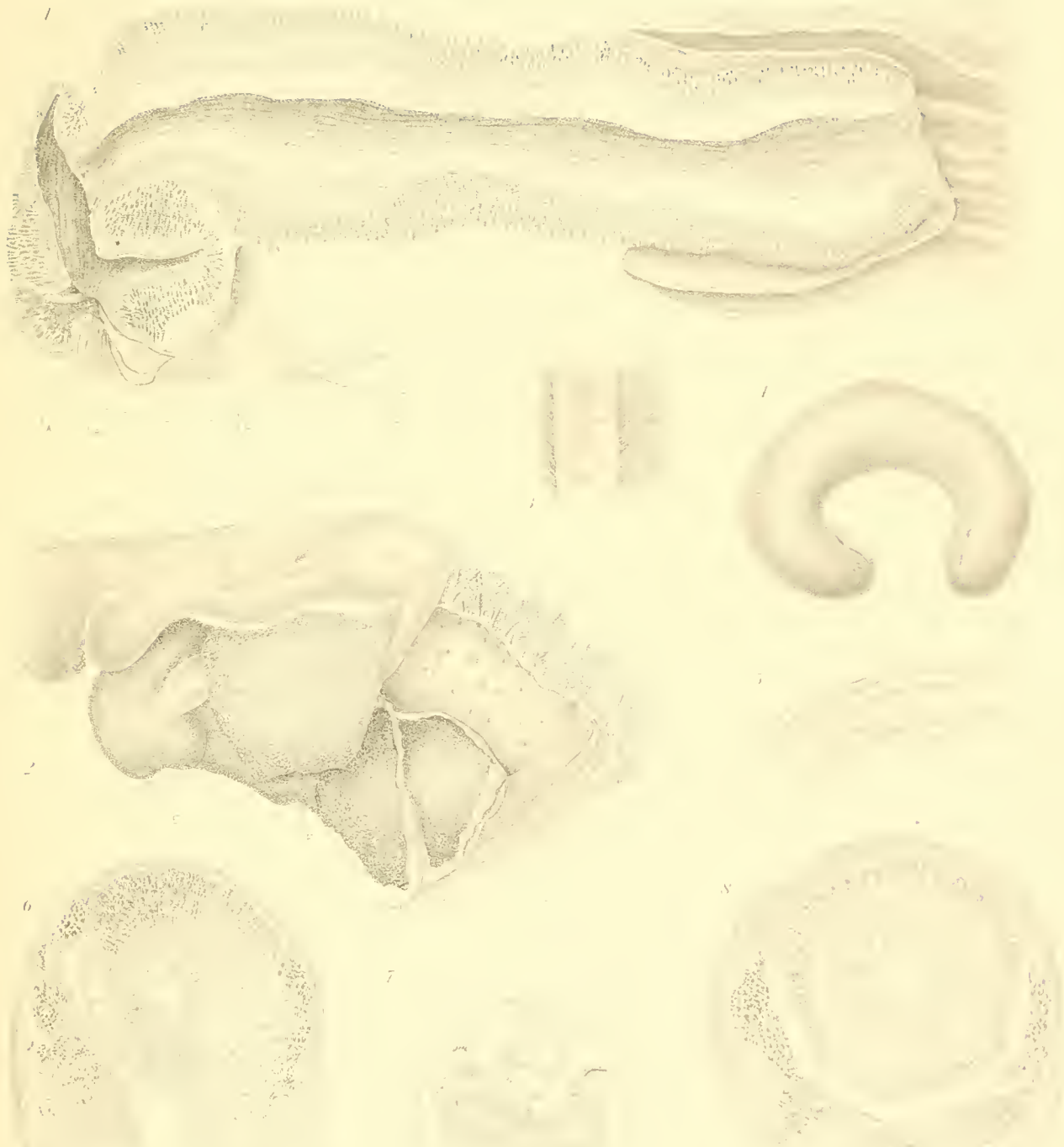


PLATE 40.

PLATE 40.

Figs. 1–4, 6–10. Cross sections of Pachymenia abyssorum. Fig. 5, Driomenia pacifica.
Figs. 1, 2, 4, 7, along lines E, F, G, H, posterior end. × 25.
Figs. 3, 6. Sections along lines A, C, anterior end.
Fig. 5. Section of Driomenia along line H, fig. 2, pl. 38.
Fig 8. Spines of Pachymenia abyssorum. × 140.
Fig. 9. Section about the posterior end of gonad.
Fig. 10. Section through body behind pharynx.

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